ANNUAL REPORT

Contract No.
Research Unit #78
Reporting Period-April 1, 1978-March 31, 1978
Number of Pages - 161

BASELINE/RECONNAISSANCE CHARACTERIZATION LITTORAL BIOTA, GULF OF ALASKA AND BERING SEA

by

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Sponsored by
U.S. Department of the Interior
Bureau of Land Management

April 1, 1978

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I. Summary of objectives, conclusions and implications with respect to OCS oil and gas development.

Our objective here is to describe the distribution and relative abundance patterns of littoral plants and invertebrates at representative sites in the eastern Gulf of Alaska. Eighteen sites were chosen for study. In addition we examined, insofar as the data permit, those factors which are likely to play important roles in structuring intertidal communities. Since biological interactions have been shown to be important to community organization we look for evidence of key interactions among our general field observations and attempt to evaluate their role in structuring the communities.

Understanding how communities are organized is important for predicting the effects of oil and gas development on community composition and on the dynamics of all populations in the community because the impact of oil on a population will depend not only on the susceptibility of individuals in that population to oil toxicity but also on the effect of oil on predators or competitors of those individuals.

Although physical disturbance such as movement of boulders at exposed sites with extensive boulder fields and ice scouring may be of overriding importance to community structure in some localities (e.g. Ocean Cape and Cape Yakataga) our studies did not adequately assess the role of biological interactions in controlling that structure.

Within the limitations of our data we examine the role of an important interaction in intertidal communities, competition for space, especially competition among dominant competitors and accompanying effects on subdominants. Our data indicate that total species richness tends to be greater in patches of intertidal area dominated by *Mytilus edulis* than in patches dominated by *Fucus distichus,* and that the difference is accounted for by increased species richness of small subdominant in *Mytilus* dominated areas. *Mytilus* does not appear to have a greater adverse effect on competitively inferior large subdominant than does *Fucus*.

The use of multispectral scanning as a technique for mapping the distribution of intertidal macrophytes needs further evaluation. Successful evaluation will require the simultaneous collection of data by multispectral scanning of intertidal areas with adequately marked algal zones and by observers on the ground.

II. Introduction

A. General nature and scope of study

The first study of the local distributuion of intertidal organisms in a locality north of Vancouver Island in the North Pacific was that of Gurjanova (1935; see also Gurjanova 1966) on Be ing Island in the Commander Islands. Hers was the only published study on the ecology of intertidal species assemblages in this region until that of Nybakken (1969). Since Nybakken there have been a number of studies of intertidal species assemblages at various localities mostly in southeastern and southcentral Alaska. With the exception of Haven's (1971) study of the effects of an unplanned experiment in Prince William Sound all these studies have been descriptive. Feder and Mueller (1972) review them (for recent additions to the list see Zimmerman et al. 1978).

B. Specific objectives

Here we describe the patterns of distribution and abundance of littoral plants and invertebrates at 18 sites in the Eastern Gulf of Alaska based on sampling conducted there in spring, summer, and early fall from 1974 through 1976. In addition we evaluate multispectral scanning (MSS) as a technique for mapping the distribution and estimating the abundance (areal coverage) of littoral macrophytes. Finally we examine species richness and the species-abundance relations among organisms in patches of intertidal area dominated either by *Mytilus edulis* or *Fucus distichus* to gain insight into the mechanisms that structure the intertidal community at upper levels.

Other aspects of our research in the eastern Gulf of Alaska are published elsewhere. Sears and Zimmerman (1977) provide maps of the general physical composition (e.g. bedrock, boulder, sand, etc.), slope, and biological *cover* of beaches from Yakutat to the southern Kenai Peninsula excluding most of Prince William Sound. Palmisano (in preparation; see also Appendix 1 of Zimmerman and Merrell 1976a) examines the composition and rates of accumulation of marine organisms in the high tidal zone (drift zone) on three beaches in the eastern Gulf of Alaska.

C. Relevance of the Study to Petroleum Development

In a recent report on the effects of organic contaminants on ecosystem processes prepared for the National Science Foundation by the Institute of Ecology Neuhold and Ruggerio (1976) stress the importance of understanding species interactions for predicting the effect of a given toxicant on an ecosystem. They conclude that "one of the largest gaps in our present knowledge concerns species interactions". Others have questioned traditional approaches to the study of the effects of toxicants, enrichment, and habitat disruption on benthic ecosystems, and have expressed the need for information on how species interact as fundamental to these studies (Lewis 1972, Spight 1976, and Gray 1976). Pollution by oil and oil dispersants has been shown to produce major changes in the abundances of algae and invertebrates indirectly by temporarily eliminating herbivores (North et al. 1964, Smith 1968, Nelson-Smith 1972) which ultimately can delay recolonization for up to 9-10 years (Southward and Southward 1978). In these studies the most important effect of oil and oil dispersants was the temporary reduction of a key biological interaction, herbivory by limpets and urchins.

111. Current State of Knowledge

There are three ways to measure the role of biological interactions. We relate them briefly here. See Connell (1975) for a fuller discussion. The first is through controlled field experiments. This is the best approach provided that a proper control can be established because it allows one to alter the abundances of the species involved in the interaction while permitting other environmental factors to vary naturally.

The second approach involves the study of "natural experiments". This is appropriate in situations where a key species may be present in a particular community in one locality but absent in a nearby locality. The main disadvantage of this approach is that it lacks a control. It is extremely unlikely that important aspects of the environment are identical at both localities except for the absence of one species

The third approach is to describe the pattern that exists in a community at one or more points in time and see whether or not it fits the predictions of the model. This is the least desirable of the three approaches, but it can detect patterns which may suggest hypotheses to test.

The descriptive approach which typically characterizes baseline studies (the present one included) almost inevitable restricts the choices among the three approaches to the description of pattern in the community. Here we consider patterns of abundance of individuals among species at upper levels in the intertidal community and try to explain them on theoretical grounds.

IV. Study Areas

The geographical area included in this report is that section of the coast of Alaska bordering the Gulf of Alaska from Yakutat (lat. 59° 32'N, long. 139° 51'W) to Port Dick (lat. 59° 13'N, long. 151° 01'W) near the southern tip of the Kenai Peninsula (Fig. 1). Five types of beaches based on substratum were designated for study. Figure 2 shows the general distribution of these beaches within the study area. Half of the study sites were on beaches composed mostly of bedrock, about 1/4 on sand beaches and the rest on boulder or mud beaches (Table 1). A detailed description of each site is included in the results section below.

V. Methods

The sampling methods that we used in the eastern Gulf of Alaska were similar to those of Zimmerman et al. (1978). We review them briefly here.

Transect lines.

Transect lines were used for systematic sampling of populations of intertidal organisms at regular intervals along their vertical distributions. The lines

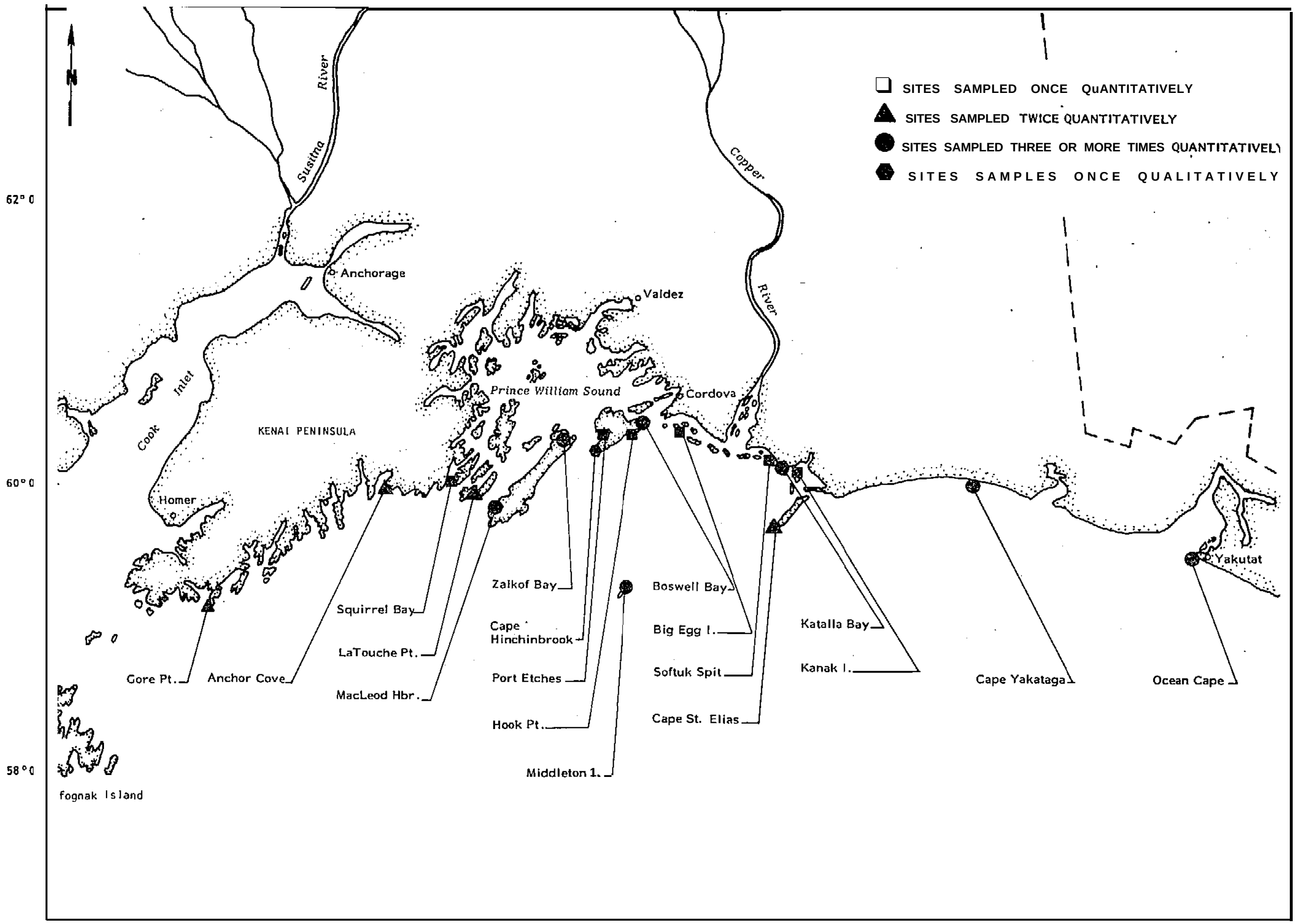


Fig. 1. Locations of sites sampled in the eastern Gulf of Alaska.

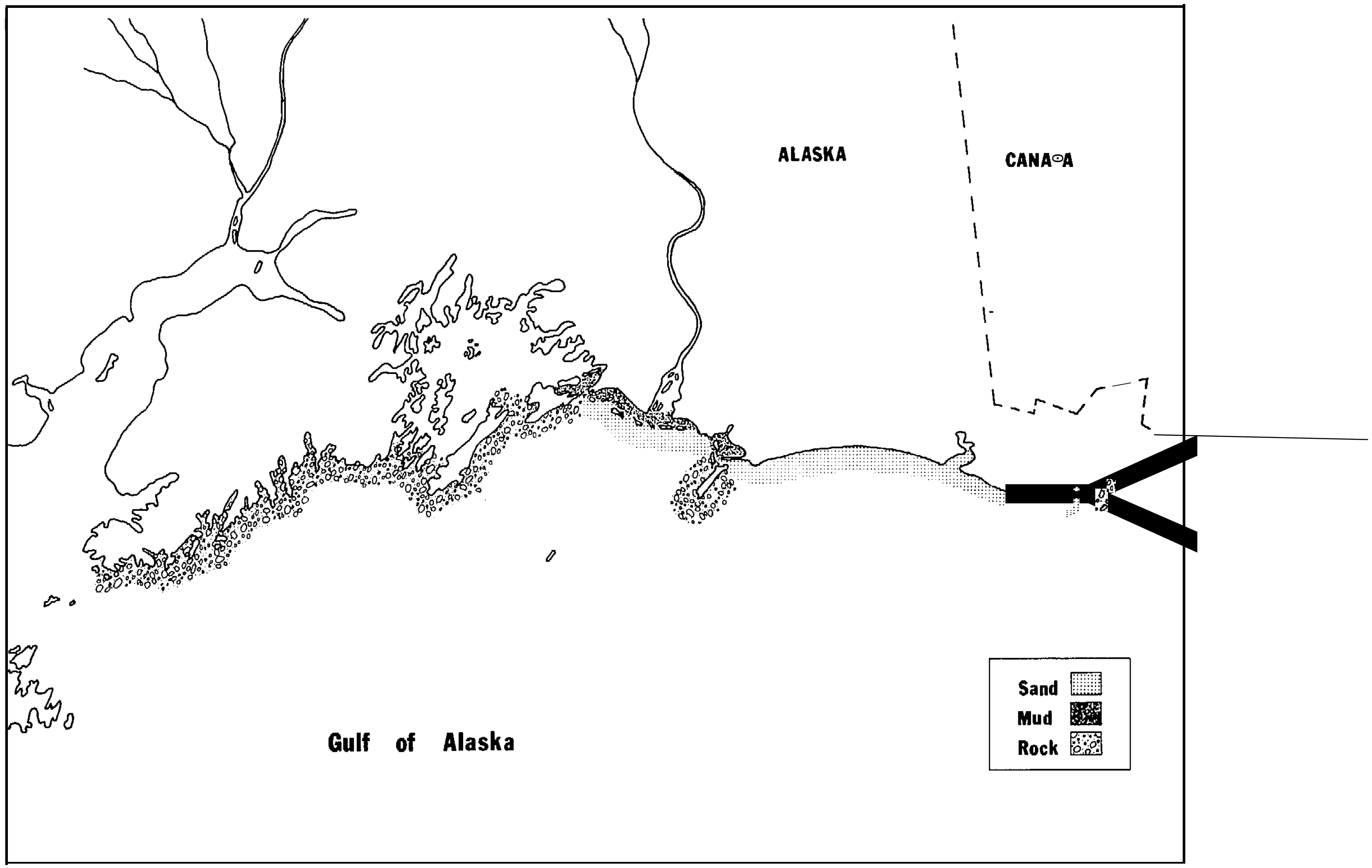


Fig. 2. Distribution of intertidal habitat types in NEGOA. Bedrock, boulder and gravel have been combined (Sears and Zimmerman, 1977).

Table 1 Description of ntertidal sites and types of samples in the East Gulf of Alaska 1974-1976.

QUANTITATIVE

Location	Substrate	Dates Sampled	Elevation Range Sampled (feet)	Sampling Method: Arrow	Sampling Method: Quantitative Collection	Sampling Method: Core	Sampling Method: Visual Enumeration	Quantitative Sample Size	Total N" of Quantitative Transects
Ocean Cape	Boulder Sand	0-11-74 0-12-74 6-10-75 9-4-75 9-5-75	+11.9 → -3.8	X	X	x	x	1/16 m^2 1-liter n = 42*	1
Cape Yakataga	Bedrock Sand	10-12-74 10-13-74 6-10-75 6-11-75 9-5-75 9-6-75	+15.6 → +2.3	X	X	x	x	1/16 m^2 1/64 m^2 1 liter n = 118*	9
Cape St. Elias	Bedrock Boulder	9-9-75 4-18-76 4-19-76	+ 9.2 → -2.8		X		x	1/16 m^2 n = 36*	2
Kanak Island	Sand Mud	4-17-76	+ 6.3 → -2.3			x		1 liter n = 23*	1
Katalla Bay	Boulder Bedrock	10-15-74 4-28-75 9-9-75	+ 8.7 → -0.9	7-	x	x	x	1/16 m^2 n = 83*	6
Softuk Spit	Sand	4-18-76	+ 3.4 → -1.4			x		1 liter n = 15*	1
Big Egg Island	Sand	4-15-76	+11.5 → -3.0			x		1 liter n = 26*	2
Boswel l Bay	Mud	9-18-74 5-1-75 9-7-75 4-14-76	+ 7.9 → -2.2	X		x		1 liter 1/16 m2 n= 133*	5

Table 1. Description of intertidal sites and types of samples in the East Gulf of Alaska 1974-1976.

QUANTITATIVE

Location	Substrate	Dates Sampled	Elevation Range Sampled (feet)	Sampling Method: Arrow	Sampling Method: Quantitative Collection	Sampling Method: Core	Sampling Method: Visual Enumeration	Quantitative Sample Size	Total N' of Quantitative Transects
Hook Point	Sand Mud	4-13-76	+5.8→ -1.4			X		1 liter n = 18*	1
Middleton Island	Mud	10-14-74 4-28-75 9-6-75	-------		X	X		1 liter 1/16 m^2 n = 19*	2
Port Etches	Bedrock	4-27-75	+5.5→ -1.6	X	X			1/16 m^2 n = 15*	1
Zaikof Bay	Bedrock	9-12-74 4-25-75 4-26-75 9-6-75	+10.2→ -2.4	X	X		-	1/16 m^2 1/8 m^2 1/64 m^2 1/32 m^2 n = 99*	4
MacLeod Harbor	Bedrock	9-16-74 9-17-74 4-24-75 9-5-75	+10.2→ +0.3	X	X		X	1/16 m^2 1/8 m^2 1/64 m^2 1/32 m^2 n = 35*	6
Latouche Point	Bedrock	4-23-75 4-24-75 9-4-75 9-5-75	+10.9→ -1.22	X	X		X	1/16 m^2 n= 67*	2
Squirrel Bay	Bedrock Boulder	9-13-74	+15.1→ +2.2	X	X		-X-	1/16 m^2 1/8 m^2 1/64 m^2 1/32 m^2 n = 41*	1

Table 1. Description of intertidal sites and types of samples in the East Gulf of Alaska 1974-1976.

QUANTITATIVE

Location	Substrate	Dates Sampled	Elevation Range Sampled (feet)	Sampling Method: Arrow	Sampling Method: Quantitative Collection	Sampling Method: Core	Sampling Method: Visual Enumeration	Quantitative Sample Size	Total N" of Quantitative Transects
Anchor Cove	Bedrock	9-15-74 9-16-74 4-22-75 4-23-75 9-3-75 9-4-75	+10.9→ -0.3	X	X		X	1/16 m² 1/64 m² 1/32 m² n= 86*	6
Gore Point	Bedrock Boulder	5-21-75 5-22-75 8-6-75	+13.2→ +1.1	X	X			1/16 m² 1/64 m² 1/32 m² n= 56*	3

* Total number of samples of all sizes taken

QUALITATIVE

Location	Substrate	Dates Sampled	Elevation Range Sampled (feet)
Cape Hinchinbrook	Boulder Bedrock	4-12-76 4-15-76	+11.38→ -0.35

were laid roughly perpendicular to the shoreline usually from the level of mean high water or above (Table 1) to the water's edge at low tide. The number of lines at each site depended on the slope, width, and biological homogeneity of the beach (Table 1).

On bedrock and boulder beaches sampling frames 1/16 m^2 in size were placed at regular intervals along the transect line. The area within each frame was photographed to obtain the coverage of obvious organisms (visual estimates of this coverage were often made as well), and then the plot was scraped to bare rock and the organisms bagged and fixed in 10% formalin.

At sandy and muddy sites a 1 "liter (10 cm on a side) corer was used to sample epi- and infaunal organisms on the transects. Often the substrate was sampled at two depths, O to -10 cm and -10 to -20 cm depending on the fluidity of the substrate, the presence and location of a reduction layer and the likely presence of macroscopic organisms as determined by taking shovelful of sand or mud and sieving it through a 1 mm screen. Two pairs of replicate samples were often collected from each point on the transect line. Larger areas were dug with shovels to estimate the relative abundance of larger less numerous organisms.

Arrow method.

The "arrow" sampling method (developed by R. Myren) is a random sampling method used primarily on vertical or near vertical surfaces such as the sides of large boulders and rock outcrops. With this method a facsimile of the area to be sampled and the general pattern of distribution of dominant organisms was sketched on a sheet of Mylar plastic. Numbered uniformly distributed dots were then placed on the sketch. The positions of a fraction (usually about 25%) of the dots were selected from a random number table. The locations on the rock surface corresponding to the randomly selected dots were marked with numbered arrows. A quadrat (1/16 m^2) was then placed at the tip of each arrow, photographed and its elevation determined (see below). The "arrow" site was not disturbed. Plots of the same size with similar biological cover in a nearby area were scraped clean of organisms which were collected for identification and enumeration.

Nested quadrats.

This method was used occasionally, primarily to study the effect of sample size (quadrat area) on species richness and diversity and to evaluate sampling variability. The results of this aspect of sampling are reported in Zimmerman and Merrell (1976b). The method involved a 1/4 m^2 frame which was divided into 16 1/64 m^2 subareas by strings stretched between opposite sides of the frame. Various sized subareas from 1/64 to 1/8 m2 were sampled.

The elevations of samples taken by all of the above methods were determined with a transit and level rod using standard surveying techniques. The reference level was the level of low tide predicted in the Tide Tables.

In addition to quantitative and qualitative collections genera"l observations of biological interactions and the distribution, relative abundance and natural history of obvious organisms were made. Minor deviations from the procedures reviewed above are included in the descriptions for each site when appropriate.

Laboratory procedures.

All samples were sorted by the Alaska Marine Sorting Center of the University of Alaska. All organisms were identified, counted (except organisms for which individuals could not be readily distinguished such as many species of algae, sponges, bryozoans, etc.), and weighed (wet weight and dry weight). Organisms from most major phyla were identified to" species. Invertebrates from the following taxa were not usually identified by the Sorting Center: Porifera, Cnidaria, Platyhelminthes, Rhynchocoela, Nematoda, Oligochaeta, Insects and Bryozoa.

The reproductive stages of the two most common genera of algae, Fucus spp and *Alaria* spp, were noted and weights for the different stages were recorded separately. Counts and weights of mussels and limpets were recorded separately for two or three size categories. Finally when most organisms had been removed and all that remained was a diverse mass of small fragments, estimates of the remaining individuals were determined by subsampling the residue.

Sources of bias and error.

None of the sampling methods used adequately sampled large and less common organisms such as starfish and urchins. With regard to intertidal community structure and how oil pollution might affect it, these two groups of organisms probably have an influence which is disproportionate to their abundance and biomass (see results section) and therefore the lack of data is particularly noteworthy.

None of the samples taken for laboratory analysis were strictly random. Whether the lack of randomness vitiates a particular statistical test depends on the questions that are asked of the data and will be discussed when each test is introduced.

The objective of this sampling program was to visit as many "representative" sites as possible and within each site to sample as many habitats as possible. Therefore, despite the large number of samples at most sites, it was difficult to obtain an adequate sample size to test specific hypotheses.

Other sources of bias and error that affect the usefulness of the data from particular sites are included in the descriptions of those sites.

VI. Results

In this section we first give descriptions of each site visited in the eastern Gulf of Alaska. Each description includes the physical description and location of the site, the distribution and abundance patterns of dominant organisms and where appropriate a discussion of factors which may be important to community structure at each site. Then we present our results of the analysis of species-richness and species-abundance relations at selected sites in the eastern Gulf of Alaska.

OCEAN CAPE, YAKUTAT

Physical Description and Location

Ocean Cape (lat. 59° 32.2'N, long. 139° 51.3'W) is at the southeastern entrance to Yakutat Bay (Plate EG-1, Sears and Zimmerman 1977; and Figures 1 and 3). This site is the most exposed of all the eastern Gulf of Alaska sites; waves to a height of 88 ft (26.8 m) have been recorded there (Wade, U.S. Coast Guard, Juneau, pers. comm.). The area we sampled is a field of boulders from cobble size to over 4 m high. Sand beaches dominate the coastline for many miles north and south of the boulder field (Fig. 2). The sand beach upon which the boulders lie is gently sloping; a 60 m transect ran from -0.4 to +2.7 ft (-0.1 to +0.8 m). We used the arrow method (Fig. 4) to sample the biota on the boulders, and collected sand cores along a transect at the border of the boulder field. Palmisano (in preparation) conducted a study of the remains of organisms in windrows on the beach in an area northeast of the Cape. Table 1 is a listing of methods, dates, and tidal range of sampling.

Dominant Organisms

Invertebrates were more abundant than macrophytes in the boulder field at Ocean Cape. Table 2 shows range of tidal elevation, range of numbers per 1/16 m^2, and height of greatest abundance for selected species. Mytilus edulis is more abundant at Ocean Cape than at any other of our northeastern Gulf of Alaska sampling sites. Mytilus was collected at every elevation we sampled except one (+11.9 ft (+3.6 m)). Balanus glandula is another abundant animal at Ocean Cape. At the tidal height where numbers of large Mytilus were most abundant (+9.5 ft (+2.9 m)) one of us (N. Calvin) noted many dead B. glandula beneath the Mytilus. Fig. 5 shows the patchily dense cover of Mytilus edulis at the lower limit

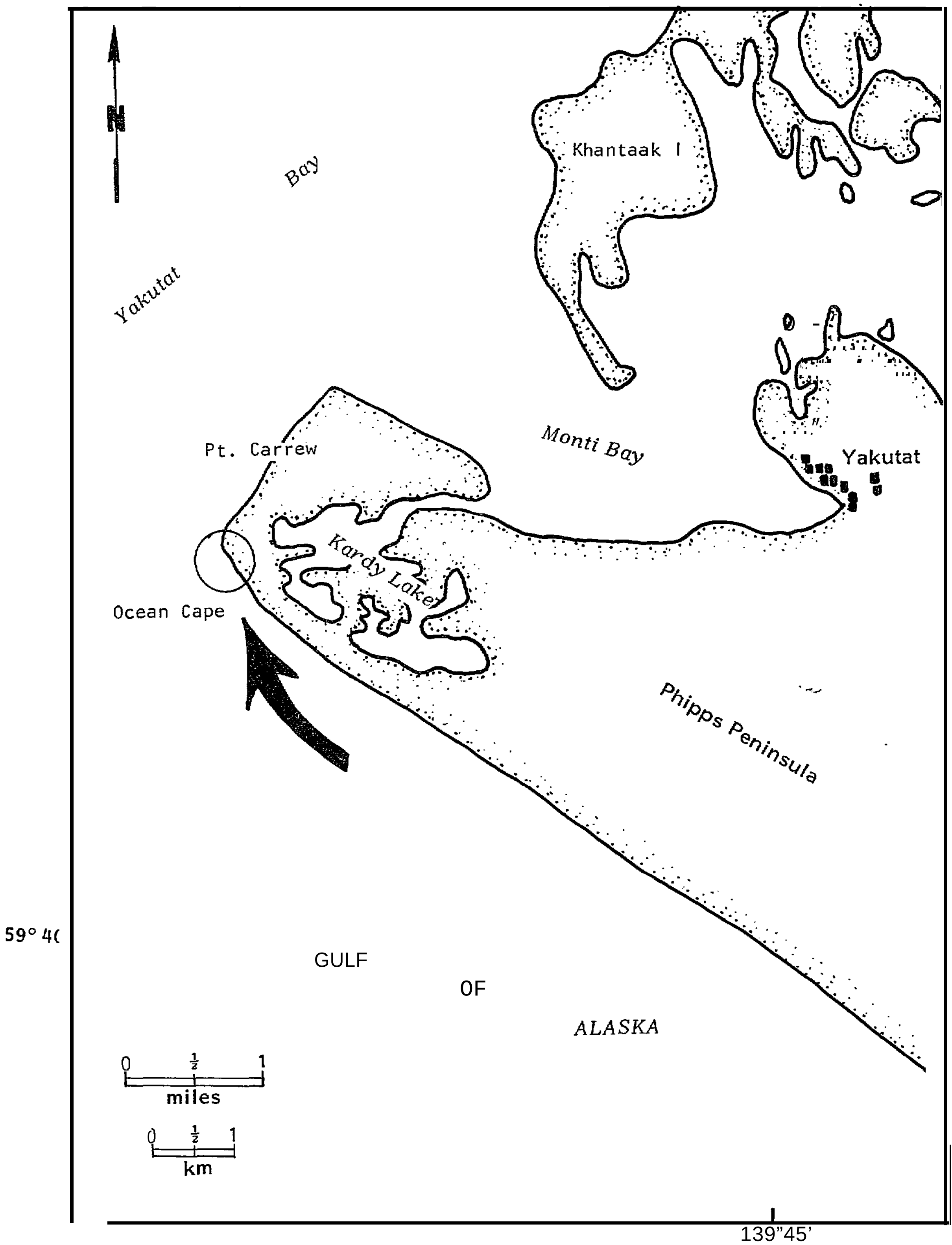


Figure 3 . Ocean Cape site.

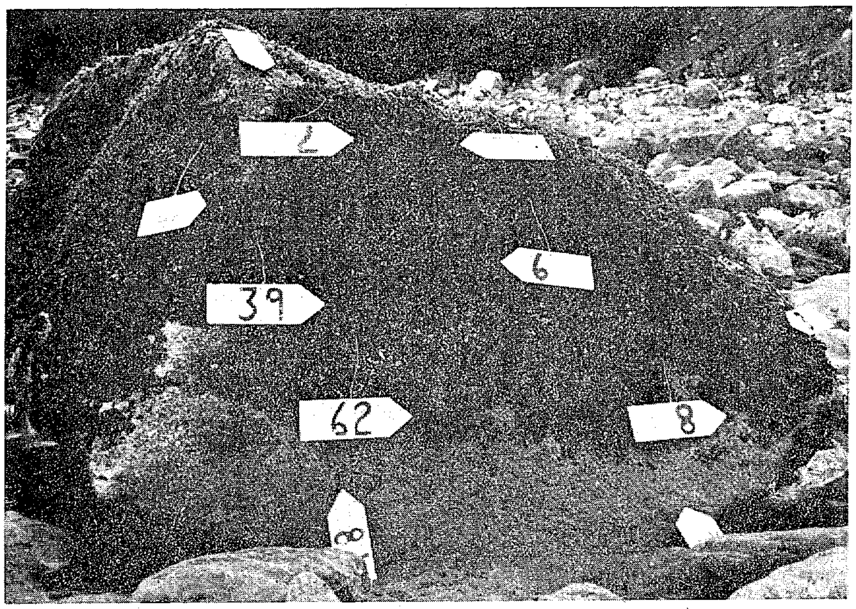


Fig. 4 . High zone boulder with heavy cover of _Mytilus edulus._ Arrows have been placed randomly for qualitative sampling. Taken in September 1975.

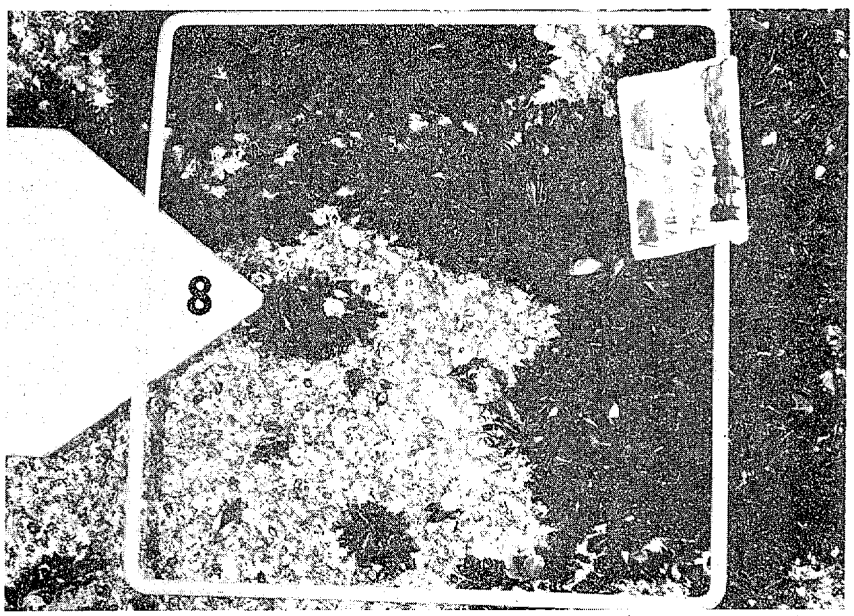


Fig. 5. Patchily dense cover of _Mytilus edulis_ (dark area) on a boulder at Ocean Cape. Taken in September 1975.

Table 2. Range of tidal elevation, numbers per 1/16 m^2, and height of greatest abundance of selected species at Ocean Cape, Yakutat, Alaska.

Species	Range of tidal elevation	Range of numbers per 1/16 m^2	Height of greatest abundance
Balanus glandula	+11.9 to +1.9 ft (+3.4 to +0.6 m)	0 to 840	+7.0 to +8.0 ft (+2.1 to +2.4 m)
Mytilus edulis			
<1.5 cm	+11.1 to -0.2 ft (+3.4 to -0.1 m)	7 to 25475	+5.5 ft (+1.7 m)
1.5 to 2.0 cm	+11.1 to +1.8 ft (+3.4 to +0.6 m)	0 to 560	+7.0 ft (+2.1 m)
>2.0 cm	+11.1 to +1.8 ft (+3.4 to +0.6 m)	0 to 550	+9.5 ft (+2.9 m)
Balanus cariosus	+11.9 to -0.2 ft (+3.4 to -0.1 m)	0 to 141	+2.7 ft (+0.8 m)

of the mussel. Balanus cariosus was common at Ocean Cape. In the range where they were most abundant we found them on the seaward side of vertical or sloping boulders. The barnacles were large, thick-walled, and often covered with mussels and algae, especially Palmaria palmata (= Rhodymenia palmata).

Predation on mussels and barnacles did not appear to be a dominant structuring factor at Ocean Cape. We did not collect large sea stars in the quadrats, but we noted a few Evasterias troschelii at the foot of boulders in the low zone. Nucella lima (= Thais lima) was found in the quadrats drilling mussels and barnacles. Numerous flatworms were present in the quadrats. Most Turbellaria are carnivorous (Hyman 1951). Glynn (1965, p. 70) has noted a polyclad worm preying on a limpet; other prey items include nematodes, annelids, snails, isopods, amphipods, barnacles bivalves and ascidians (Hyman 1951). The flatworms in our samples were not identified specifically, and we do not have observations on their food habits. Limpets, fly larvae, and the collembolan, Anurida maritima, are described by Lewis (1964, p. 75-76) as minor fauna of barnacle dominated shores. All of these were present at Ocean Cape, especially in the zone where B. glandula is most abundant; the limpet found most commonly was Collisella pelta.

Macrophyte cover was not heavy. Fucus distichus was most abundant on boulder tops in the high zone (Figs. 6 and 7) Odonthalia floccosa was found on the sides of boulders, mostly in the high zone. Low zone algae were Palmaria palmata and several species of Alaria. Porphyra sp. was common in June but rare in the fall (Fig. 6). We found it on the tops of very large boulders and completely covering low boulders in the high zone.

The sand cores we collected in September 1975 contained very few species and individuals. We found a mysid, crab larvae, a calanoid copepod, fly larvae, and three species of amphipods (Appendix 2).

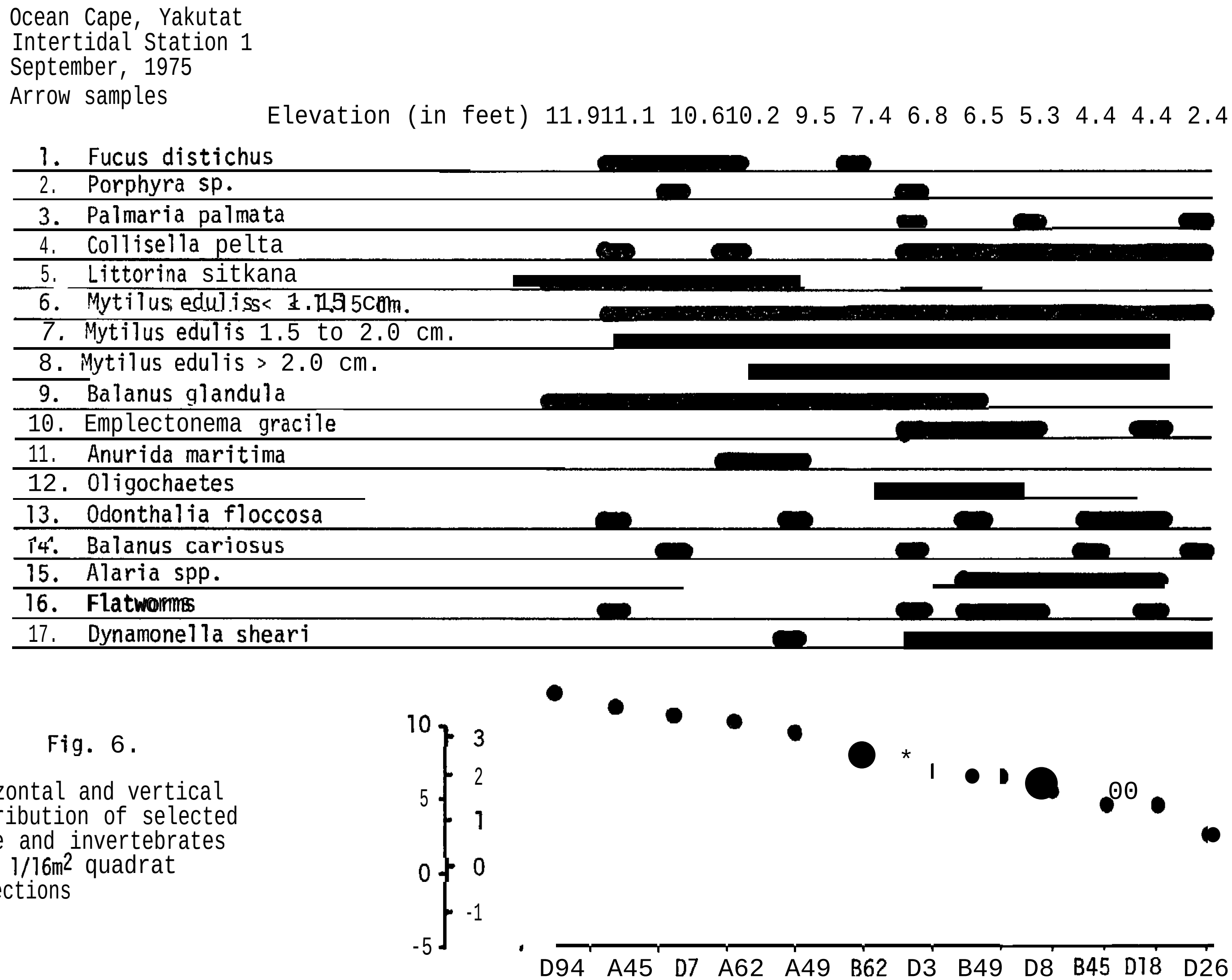


Fig. 6.

Horizontal and vertical distribution of selected algae and invertebrates from 1/16m² quadrat collections

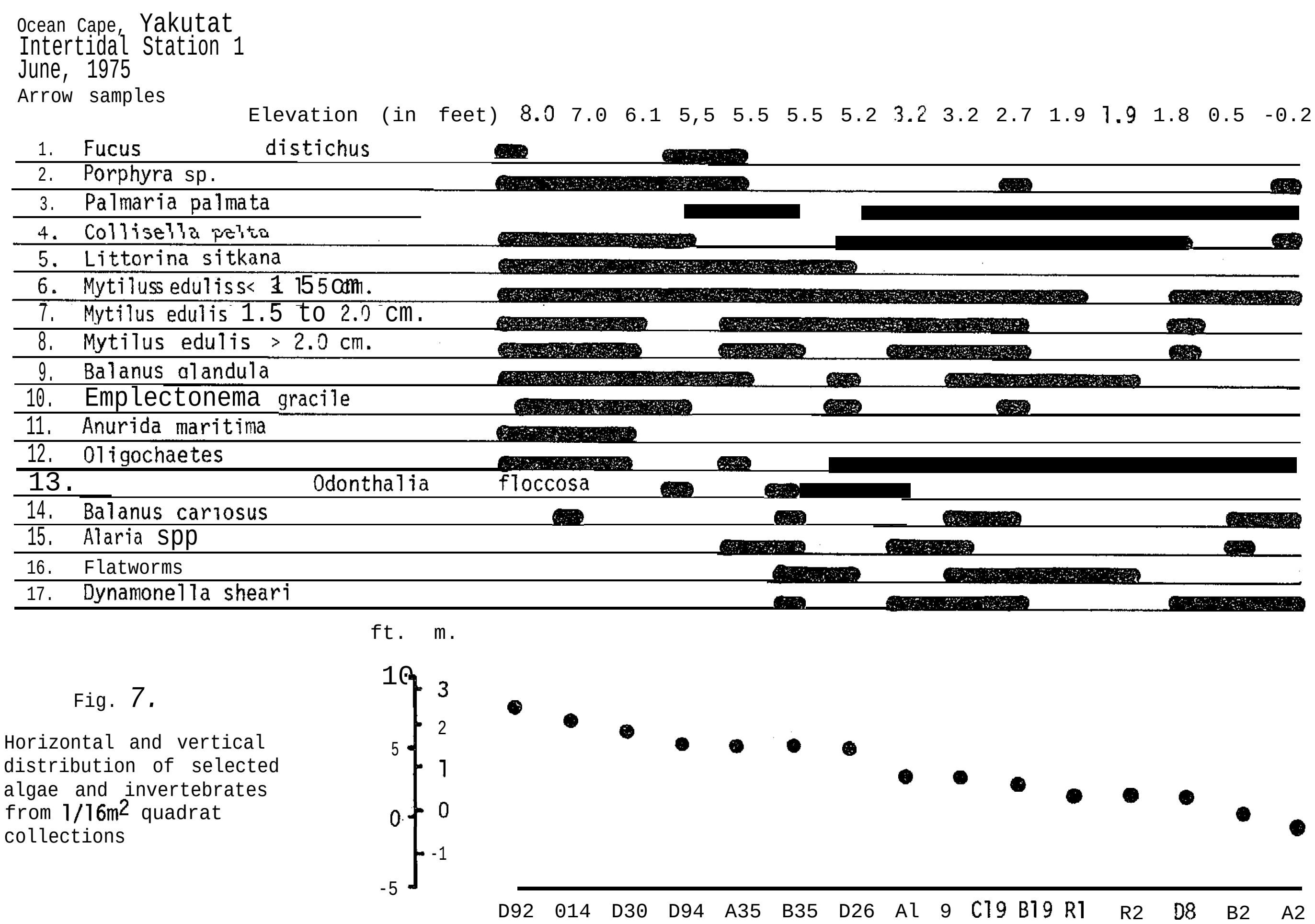


Fig. 7.

Horizontal and vertical distribution of selected algae and invertebrates from $1/16 m^2$ quadrat collections

Interactions between *Mytilus edulis*, *Balanus glandula*, and *Balanus cariosus* would be interesting to follow at Ocean Cape. Lewis, in Stephenson and Stephenson, (1972, p. 362) suggests that in the British Isles, "...the almost erratic local distribution of *Mytilus* simply reflects stages in irregular cycles of settlement, competition with barnacles, predation, denudation, and resettlement, which vary in phase from one site to another". On the basis of a few short visits to this site it is impossible to determine whether such a cycle occurs at Ocean Cape, and if so, what stage of it we were observing.

CAPE YAKATAGA

Location and Physical Description

Cape Yakataga (lat. 60° 3.8'N, long. 147° 25.9"W) is a bedrock reef projecting into the Gulf of Alaska along the coast northwest of the Alaska Panhandle. (Plate EG 12, Sears and Zimmerman 1977 and Figs. 1, 8, and 9). The coast of Alaska from Icy Bay (17 m (31.4 km) east of Cape Yakataga) to Cape Suckling (24 miles (44.5 km) west of Cape Yakataga is sand beach except for Cape Yakataga (Fig. 2). The area of the reef we sampled is a mudstone and conglomerate platform with two prominant hummocks. Fossil shells are common in the bedrock. The platform is covered with a film of standing water up to 4 cm deep. Sand is often swept onto the platform by wave action; during some periods the layer is thin, but following storms sand may accumulate to a depth of about 10 cm. glacial ice (Fig. 10), presumably from Icy Bay, has been observed on the beach (John Palmisano, pers. comm.). Table 1 is a synopsis of sampling at Cape Yakataga. We were not able to sample the reef at the water's edge because continuous surf made it impracticable (Fig. 11).

Dominant Organisms

Cape Yakataga is characterized by small numbers of individuals of many species. Many of the species were ephemeral or in very patchy distribution, being collected only in one season or year. *Mytilus edulis* is the only species found along

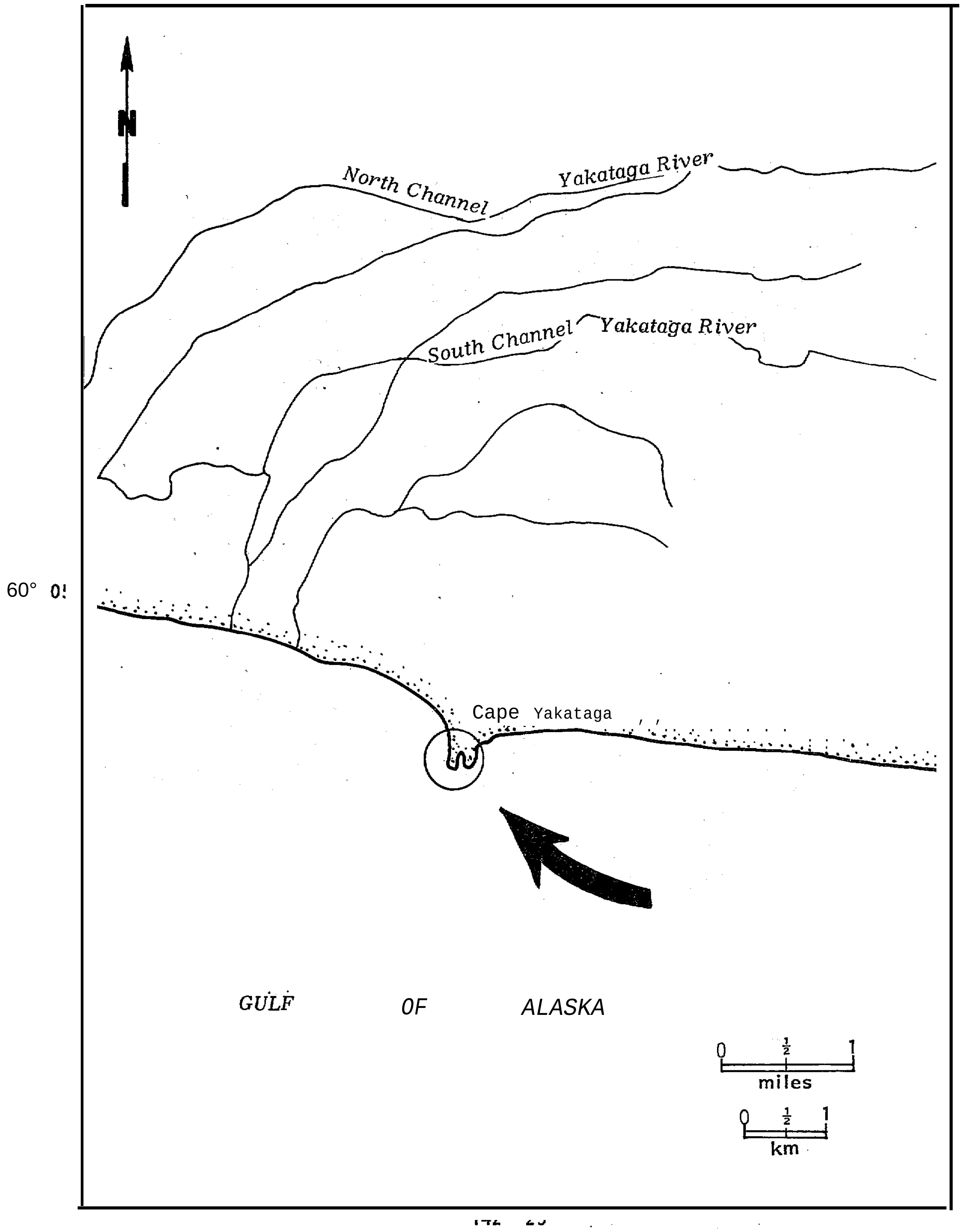


Figure 8 . Cape Yakataga site.

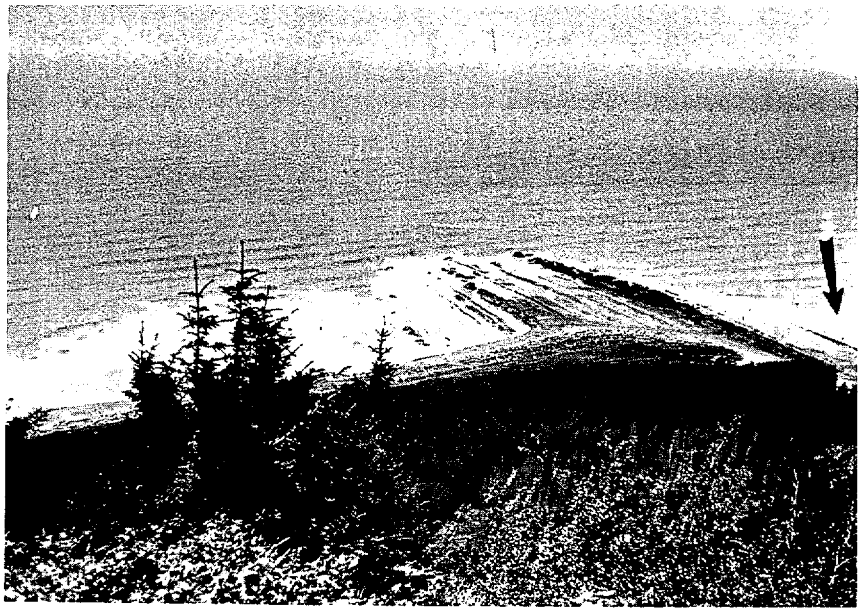


Fig 9. Bedrock reef at Cape Yakataga. Sampling area is at extreme right of reef (arrow) . Taken in June 1976,

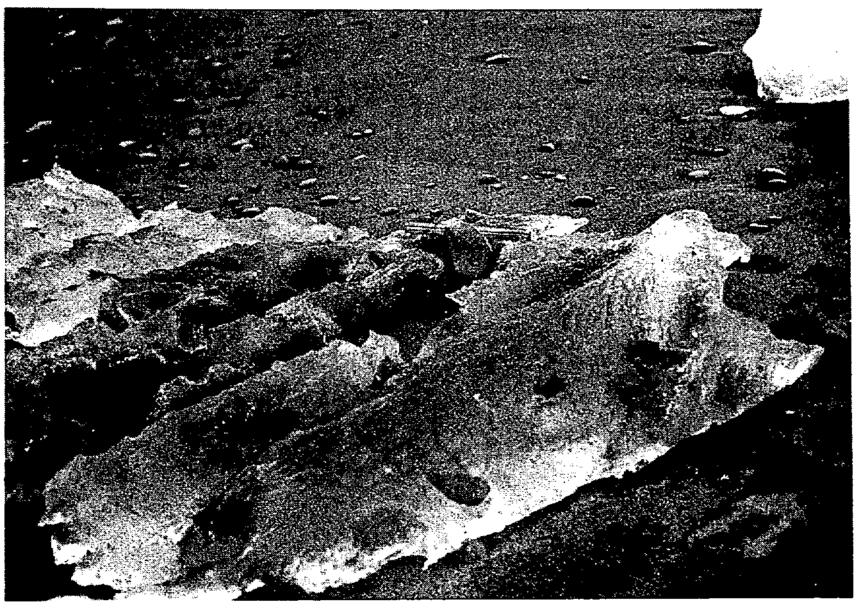
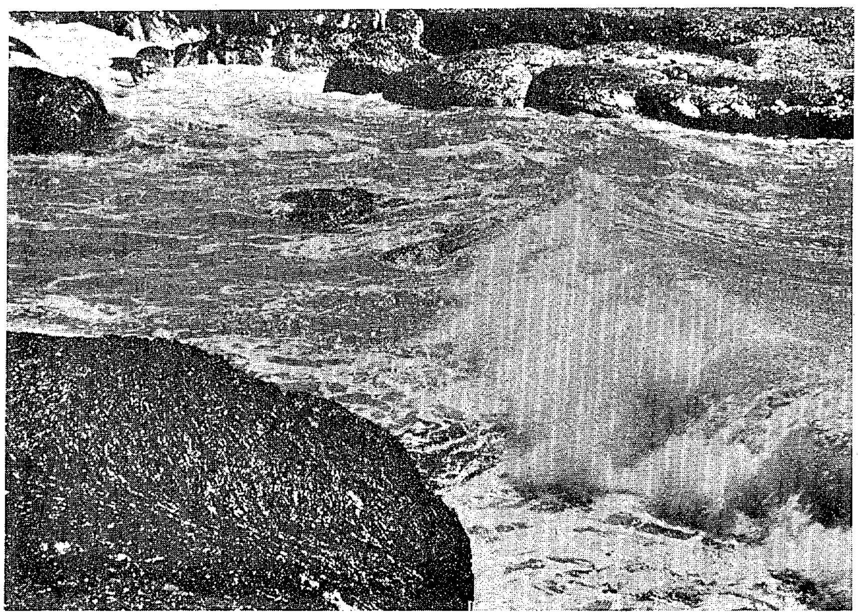


Fig .10. Glacial ice on the beach at Cape Yakataga. Ice scouring may inhibit the establishment of stable association of attached biota. Taken in February 1975,



Fig, 11. Surf zone at Cape Yakataga . The outer edges of the reef had surf continuously, making sampling impractical . Taken in June 1976,

Fig. 12. "Upper hummock" transect. Note sand and standing water on bench between hummocks. Taken in September 1975.

all three transects in all seasons. All of the Mytilus were 1.5 cm except for one quadrat on the "upper hummock" transect in September 1975, where there were 253 Mytilus < 1.5 cm; 4, 1.5 - 2,0 cm; and 6 > 2.0 cm. Tables 3, 4, and 5 show the relative frequency and number or weight of selected species collected along three transects during three sampling periods at Cape Yakataga. . Appendix 1 lists all species collected at Cape Yakataga for all sampling visits.

Although stable associations were not evident, we did note that mussels and barnacles were most abundant on the landward side of the hummocks, especially on the lower hummock (Figs. 12 and 13). One of the landmarks we used for arrow sampling on the lower hummock was a large colony of sabellid worms, Eudistylia sp, which grew in a fissure at the base of the hummock and thus was offered some protection. Limpets, especially Collisella pelta, were collected in some of the quadrats, but they were more abundant on the higher bedrock reef southeast of of the sampling site. Rounded cavities had been worn in the rock and most of these depressions were occupied by large limpets, mostly Notoacmea persona. Generally, Littorina sitkana is the most abundant gastropod on rocky intertidal beaches along the Gulf of Alaska, at Cape Yakataga however, Lacuna marmorata was generally more abundant than Littorina sitkana although numbers and distribution of each species varied.

Several species of filamentous green and brown algae were collected in quadrats. These were more numerous than other algal groups. In a recolonization study at Amchitka, Alaska, Lebednick and Palmisano (1977) found that the order of succession in a disturbed area was (1) diatoms and filamentous brown and green algae, (2) ulvoids, (3) macrophytic red and brown algae. Table 6 shows numbers of these groups collected along each transect during each sampling period at Cape Yakataga. The predominance of filamentous browns and green algae and diatoms

Table 3. Relative frequency and average number (invertebrates) or weight in grams. (algae) for selected species per 1/16 m^2 along the "*Fucus*" transect for three sampling periods, Cape Yakataga.

Species	Date October 1974 Relative Frequency	Total Species 33 Average No. or Wt.	Date June 1975 Relative Frequency	Total Species 38 Average No. or Wt.	Date September 1975 Relative Frequency	Total Species 46 Average No. or Wt.
Fucus distichus	7/8	52.0 g	5/7	6.4 g	7/13	84.9 g
Odonthalia floccosa	7/8	2.4 g	4/7	1.2g	7/1 3	22.1 g
Lacuna vincta	4/8	22	0	0	0	0
Lacuna marmorata	5/8	60	2/7	5	5/13	9
Mytilus edulis <1.5 cm.	8/8	72	7/7	121	13/13	254
Flatworms	5/8	3	0	0	5/13	14
Balanus glandula	4/8	14	2/7	1	5/13	69
Amphipods (5 sp.)	5/8	4	3/7	1	12/13	72
Pylaiella littorals	2/8	.01 g	7/7	0.8 g	10/13	20.2 g
Collisella pelta	3/8	1"	5/7	4	6/13	3
Palmaria palmata	1/8	.001 g	6/7	0.8 g	8/13	1.9 g
Filamentous diatoms	0	0	7/7	0.9 g	0	0
Diptera larvae	0	0	5/7	2	7/13	84

Table 4. Relative frequency and average number (animals) or weight in grams (algae) of selected species per 1/16 m^2 quadrat along the "upper hummock" transect for three sampling periods, Cape Yakataga.

Species	Date October 1974 Relative Frequency	Total Species 32 Average No. or Wt.	Date June 1975 Relative Frequency	Total Species 40 Average No. or Wt.	Date September 1975 Relative Frequency	Total Species 34 Average No. or Wt.
Mytilus edulis <1.5 cm.	5/5	419	10/10	913	11/11	723
Fucus distichus	5/5	3.6 g	10/10	31.2 g	9/11	29.9 g
Balanus glandula	5/5	242	9/10	160	10/11	522
Diptera larvae	1/5	19	10/10	47	5/11	85
Palmaria palmata	0	0	9/10	16.0 g	8/11	28.8 g
Pylaiella littorals	0	0	8/10	15.3 g	11/11	15.8 g
Littorina sitkana	2/5	2	8/10	57	7/11	114
Littorina scutulata	0	0	1/10	2	7/11	11
Oligochaetes	3/5	148	8/10	254	6/1 1	201
Lacuna marmorata	5/5	112	0	0	3/11	10
Collisella pelta	3/5	3	4/10	3	6/11	10
Ectocarpus simulans	3/5	43.1 g	1/10	0.5 g	1/11	unknown
Sphacelaria sp.	0	0	4/10	1.9 g	6/11	16.5 g
Amphipods	4/5	41	6/10	29	8/11	71
Porphyra sp.	0	0	8/10	2.3 g	7/11	16.3 g

Table 5. Relative frequency and average number (invertebrates) or weight in grams (algae) for selected species per 1/'16 m^2 along the "Palmaria" transect for two sampling periods, Cape Yakataga.

Species	Date June 1975 Relative Frequency	Total Species. 27 Average No. or Wt. per 1/16m^2	Date September 1975 Relative Frequency	Total Species 36 Average No. or Wt. per 1/16m^2
Palmaria palmata	6/6	37.8 g	8/8	27.3 g
Amphipods (4 sp.)	4/6	6	8/8	23
Mytilus edulis <1.5 cm,	6/6	848	8/8	262
Lacuna marmorata	6 / 6	83	4/8	31
Sphacelaria sp.	4/6	2.5 g	8/8	4.2 g
Odonthalia floccosa	1/6	0.2 g	6/8	4.2 g
Pycogonids	2/6	2	8/8	12
Pylaiella littorals	1/6	.001 g	6/8	1.8 g
Balanus glandula	1/6	<1	5/8	7
Typosyllis sp.	3/6	2	6/8	7
Eteone longs	3/6	4	5/8	5
Petalonia fascia	0	0	5/8	0.6 g

Fig. 13. "Palmaria bench"; site of Palmaria transect, and lower hummock showing arrows in place. Taken in June 1975.

Table 6, Number of species of (1) filamentous green and brown algae, and diatoms, (2) ulvoids, (3) macrophytic red and brown algae collected along three transects during three sampling periods at Cape Yakataga.

Algal Group	October 1974 No. of species *F	H	June 1975 No. of species F	H	P	September 1974 No. of species F	H	P
Group 1	13	8	8	12	5	13	“8	5
Group 2	2	1	2	4	0	1	2	1’
Group 3	4	5	7	6	4	5	5	2

* F = Fucus, H = Hummock, P = Palmaria

over other groups seems to indicate that Cape Yakataga is a disturbed site. In addition to wave action, periodic accumulation of sand, and glacial ice drifting onto the beach, erosion at Cape Yakataga is a visible process; residents of the area have observed changes in the beach from year-to-year (M. Eggebrotten, pers. comm.). All of these factors combine to make Cape Yakataga a difficult place for any group of organisms to form stable associations.

CAPE ST. ELIAS, KAYAK ISLAND

Location and Physical Description

Kayak Island is a narrow island, 28.2 km long, jutting into the Gulf of Alaska in a southwesterly direction (Fig. 1). Its extension into the currents of the Alaska Gyre and the prevailing southeasterly winds result in extensive drift accumulations on the southeast shore of the island. The width of the drift zone approaches 1/2 km in places along the coastal bench indicating that this shore is a site for the potential accumulation of floating pollutants.

Cape St. Elias (lat. 59° 47.8'N, long. 144° 36.3'W), is at the southwest tip of Kayak Island (Fig. 14). The average annual temperature is 4.4°C and the average annual precipitation is 279.4 cm, with 180.3 cm of snow (25.4 cm of snow = 1 cm of rain) (Anonymous 1964). There are several shoals and reefs in the vicinity of Cape St. Elias which may break the full force of waves coming from the Gulf of Alaska, but few directly offshore of our sampling site which is about 0.8 km north of the Cape on the western shore of the island. The site is a low-gradient bedrock platform (Sears and Zimmerman 1977, Plate EG-18) cut by shallow channels and with dams which restrict tidal drainage. There are a few small boulders strewn across the platform; these are more densely aggregated at the head of the beach (Fig. 15 and 16).

Dominant Organisms

Macrophytes were more obvious than invertebrates at the Cape St. Elias

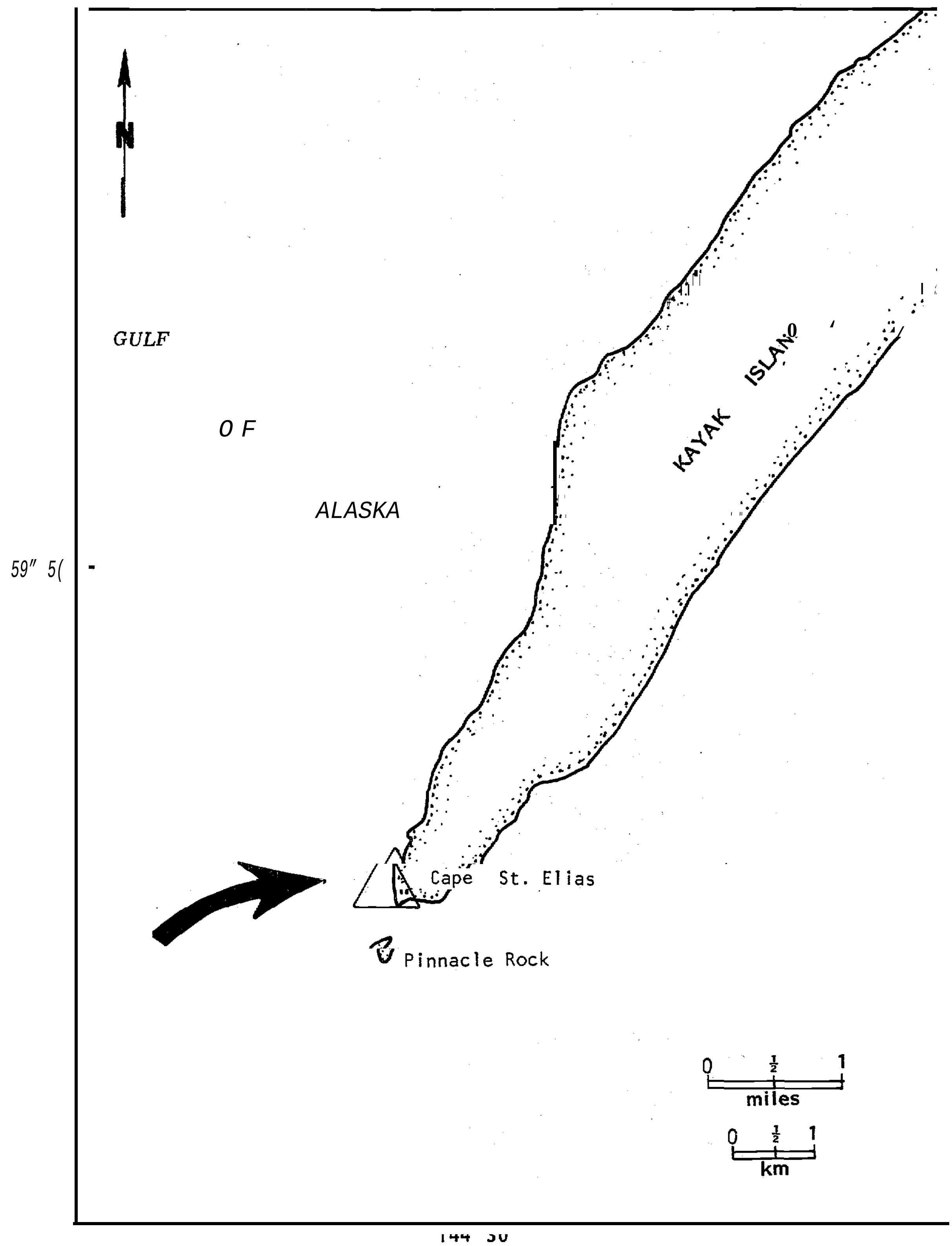


Figure 14. Cape St. Elias site.

Fig.15. View of transect looking toward the cape. Cape St. Elias rises steeply from the beach and shades it from the east. Taken in April 1976.

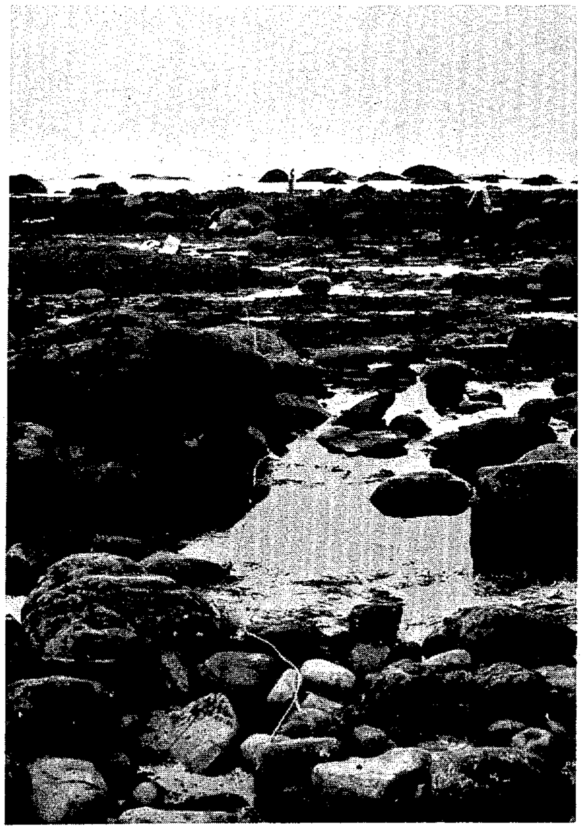


Fig.16. View of transect looking seaward. The sampling site is a low gradient platform strewn with boulders. Taken in April 1976.

sampling site. Appendix 1 is a list of all species collected at Kayak Island during all sampling visits. The distributions of some selected intertidal organisms are shown in Figs. 17 and 18 for fall 1975 and spring 1976. Dates and methods of sampling at Kayak are listed in Table 1. In April 1976 we made percent-cover estimates at each meter along a 117-m transect using 1/16 m^2 quadrats. The cover of five dominant species of algae on the quadrats averaged 50%. Many other species of algae were present in smaller amounts. Palmaria palmata (L.) Stackhouse (=Rhodymenia palmata (L.) Grev.) (Guiry 1974), was most abundant with 21% cover. Lewis (1964, p. 99) has observed in Scotland that Palmaria is most abundant on flat, slow-draining platforms on shores dominated by mussels. Mussels are sparse at this site, but the slope and topography of the beach were apparently favorable to Palmaria. Cape St. Elias, a steep rocky ridge about 1 m (1.6 km) long and 1665 ft (507.5 m) high, shades our site from the East. Lewis (1964) has also noted that Palmaria thrives in shaded situations, so this may be another factor contributing to its abundance. In the spring much of the Palmaria was old-growth, thick, leathery, nearly black, and covered with an epiphytic growth of Ectocarpus spp. and Monostroma zostericola. Small, red, new blades of Palmaria were also present. In the fall most blades were bleached. Munda (1972 p, 14) in her observations in the coastal shallows of Iceland, noted that Palmaria was yellow (bleached) and covered with epiphytes in August. At Cape St. Elias in the fall only small amounts of Ectocarpus were present as epiphytes on Palmaria.

The "Odonthalia-Rhodomela complex", consisting mostly of Odonthalia floccosa with smaller amounts of Rhodomela larix, averaged 19% cover per quadrat. The two species are difficult to separate morphologically. They often occur together and have no apparent ecological differences so we combine them here. Odonthalia-Rhodomela also occur abundantly on several slow-draining, low-gradient beaches on southern Kodiak Island (Zimmerman et al. 1978). Their finely divided form provides an excellent refuge for small motile invertebrates such as amphipods,

Cape St. Elias
Intertidal Station 4
September 1975

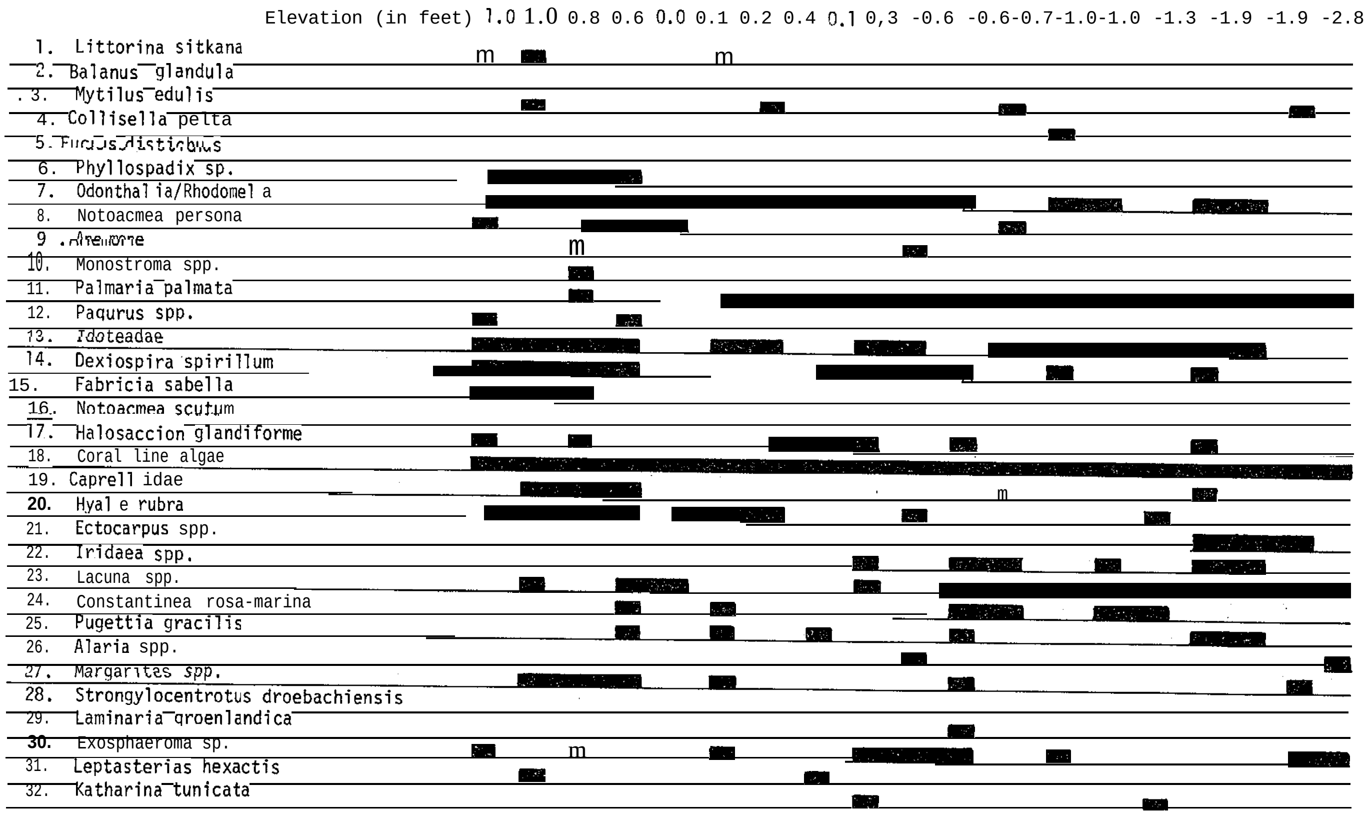
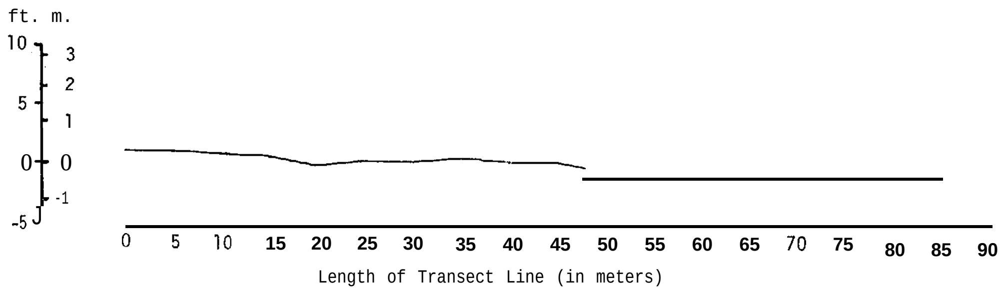


Fig. 17

Horizontal and vertical distribution of selected algae and invertebrates from 1/1 6m2 quadrat collections along a transect 1 inc.



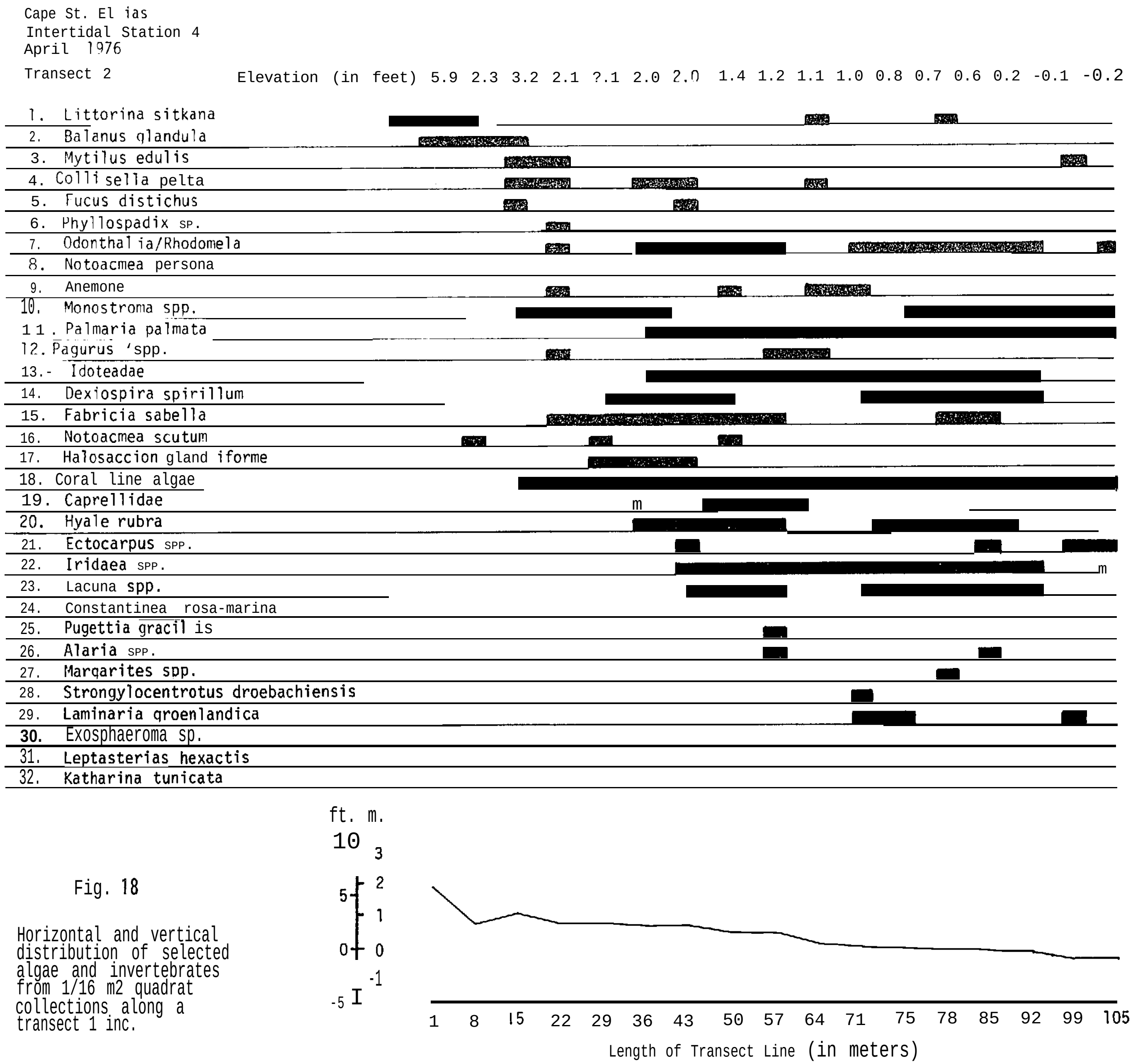


Fig. 18

Horizontal and vertical distribution of selected algae and invertebrates from 1/16 m2 quadrat collections along a transect line.

isopods, and gastropod. Turtonia occidentals, a bivalve, attaches its byssal threads to these species as well as other Rhodophycean turf species. The Turtonia-rhodophycean association was also common at Kodiak, and at Latouche Point (see description of Latouche Point).

Monostroma spp. showed an estimated average cover per quadrat of 9% in the spring, but was not collected in the fall. Its presence as an epiphyte on Palmaria was especially noteworthy because of its unusually heavy cover. Palmaria had only small amounts of epiphytic Ectocarpus spp. Non-epiphytic Monostroma also occurred only in the spring; its biomass was less than that of the epiphytic Monostroma.

Several species of coralline algae, articulated and encrusting, were collected at Cape St. Elias. We observed corallines growing at elevations of -0.7 to +2.0 ft (-0.2 to +0.6 m), higher than would be expected. Lewis (1964, p 150-1) has observed corallines growing at high elevations in pools and postulates that dessication is the most important factor controlling their upper limits on open rock.

Phyllospadix sp. averaged 6% cover along the transect; this species was poorly sampled by the transect, however. We observed it growing in thick patches in and along the borders of shallow pools high on the beach, probably at about the +2.0 ft (0.6 m) level, and beginning at about 75 m on the transect. When we walked along the beach we noted that in places it formed a belt several meters wide, Phyllospadix was also observed to grow abundantly on slow-draining beaches on Kodiak Island, especially at Cape Sitkinak and the Geese Islands (Zimmerman et al. 1978). Latouche Point also had a heavy cover of Phyllospadix, but this is probably due more to deep tide pools than to a low gradient beach.

Barnacles and mussels were sparse at Cape St. Elias, but motile and cryptic species were common. No barnacles were collected in September 1975, but no collections were made above the +1.0 ft (+0.3 m) elevation. In April 1976 Chthamalus dalli was abundant at the +5.9 ft (+1.8 m) level on a large boulder and was present (5 per quadrat) in two other 1/16 m^2 quadrats at about the +2.0 ft (+0.6 m) level. *Balanus glandula* was collected in five quadrats from +1.1 to +5.9 ft (+0.3 to +1.8 m) elevation in numbers ranging from 5 to 550 per quadrat ($\bar{x}$ = 199).

Mytilus edulis was collected in September 1975 and in April 1976. It was found at elevations ranging from -1.9 to +3.2 ft (-0.6 to +1.0 m) in numbers ranging from 2 to 25 per quadrat ($\bar{x}$ = 7.5). All of the *Mytilus* were <1.5 cm in length. *Modiolus modiolus* averaged 16 per quadrat in two quadrats in September 1975. Only one *Modiolus* was collected in April 1976. All of these mussels were small.

-Channels cut in the rock provided suitable habitat for urchins. Five *Strongylocentrotus droebachiensis* were collected at the +0.8 ft (+0.2 m) level. *S. franciscanus* was observed in the intertidal area away from the transect; this species is usually found subtidally.

The rock at our collecting site is a friable mudstone. It may be too easily eroded by wave action, drift logs, and tumbled boulders for sessile organisms to to become well established. Species which find refuge in pools and channels are able to survive, as well as small, motile invertebrates which cling to algae or hide in crevices.

KATALLA

Location and Physical Description

Katalla (lat. 60° 16.5'N, long. 144° 36.5'W) is a south-facing beach on the north shore of the Gulf of Alaska, and is fully exposed to the oceanic conditions of the Gulf (Figs. 1 and 19). Shoal waters offshore cause oceanic swell to pile up creating a heavy surf there. The sampling site is a low-gradient reef composed of cobbles and small, large, and occasionally very large boulders surrounded on all but the seaward side by sand beach. (Sears and Zimmerman 1977, Plate EG-20). Table 1 lists dates and sampling methods used at Katalla.

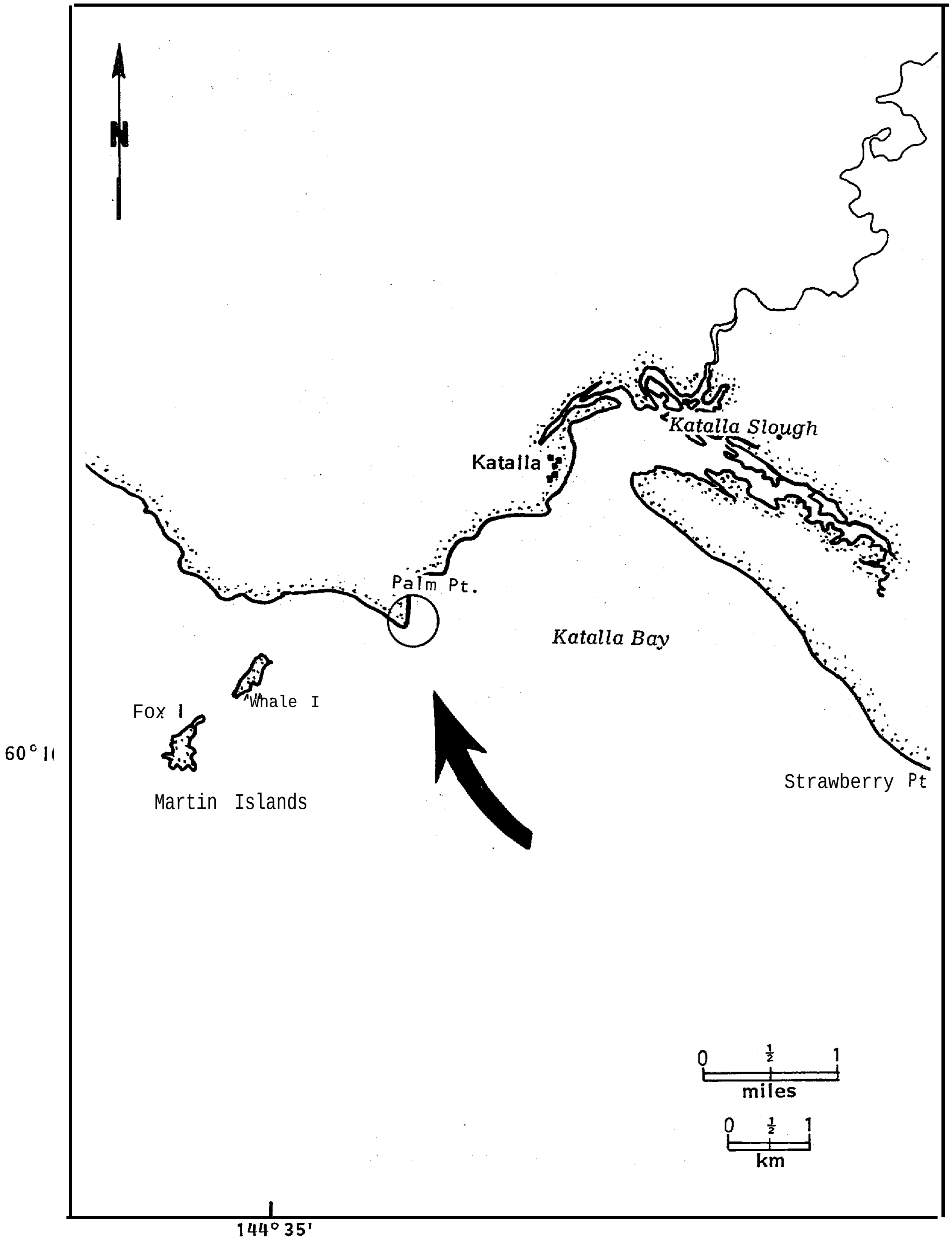


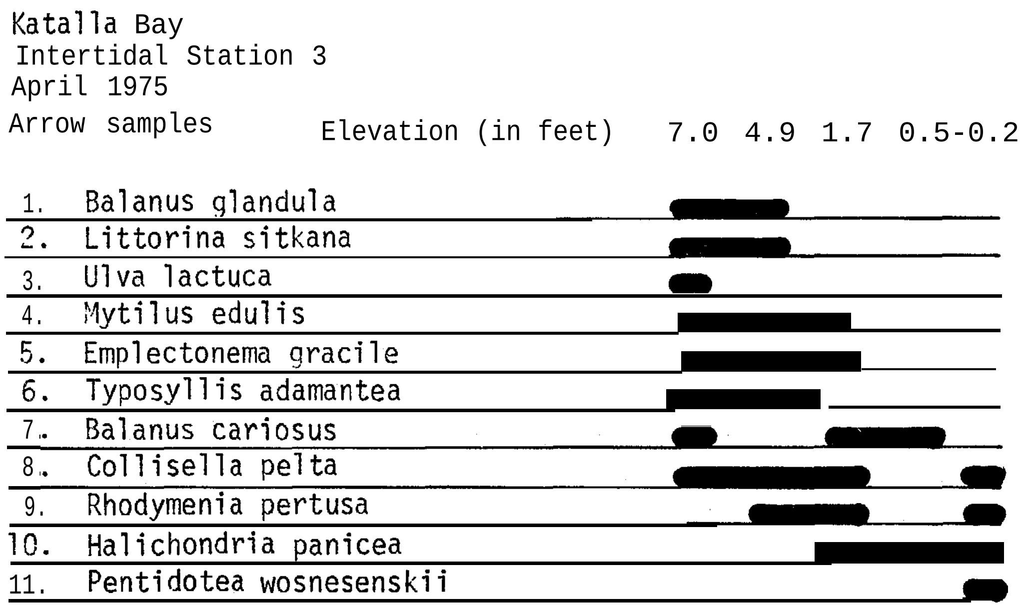
Figure 19 . Katalla Bay site.

Appendix 1 lists all species collected at Katalla for all sampling visits. Fig. 20 shows the distribution of some selected species from the "arrow" sampling, April 1975.

At our study sites most of the sessile organisms were associated with the largest boulders, particularly on the shoreward sides. We sampled one of these boulders with the "arrow" sampling method (quadrat size 1/16 m^2) in April 1975 (Figs. 20 and 21). The red alga, Porphyra sp., was recorded at the highest level that we sampled on the rock (+13.1 ft (3.9 m)). The upper limit of barnacles began about +11 ft (+3.3 m) and increased to a coverage of about 50% on one quadrat at +9 ft (+2.7 m) (arrows 18 and 20 in Fig. 21,). At +7 ft (+2.1 m) primary space was completely covered by barnacles and mussels (arrows 8 and 30, Fig. 21). A 1/16 m^2 sample scraped from the rocks elsewhere, but at the same tidal level as and in a patch of intertidal area superficially similar to that containing "arrow" plot 30 contained 18 species of organisms including 2439 Mytilus edulis (wt = 1035 gin), 780 Balanus glandula, 120 B. cariosus, littorines, worms (5 species), and minute quantities of the algae, Scytosiphon lomentaria and Ulva lactuca. At about +5 ft (+1.5 m) mussel and barnacle cover was slightly less (arrow 35 and 45, Fig. 21), but species richness was about the same. A sample scraped from rock at this level contained 19 species.

Below the zone of heavy Mytilus cover (about +2 ft (+0.6 m); arrow 3, Fig. 21) B. cariosus increased in abundance. M. edulis was represented mainly by tiny individuals in that quadrat. The +2 ft level marked the approximate upper limit of Halichondria panicea. The algae Rhodymenia pertusa and Polysiphonia hendrii were the only species of algae collected at this level.

At the lowest level studied (-0.2 ft (-0.6 m); arrows 10 and 11 Figs. 21 and 22) Halichondria panicea biomass was great (620 gm wet wt in one 1/16 m^2 sample). The sample of high biomass scraped from rock at the same level as arrow 10 contained 12 other species, primarily worms and amphipods. Barnacles were albsent.



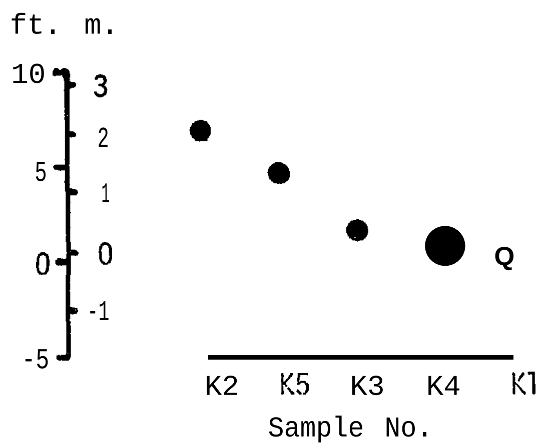


Fig. 20 .

Horizontal and vertical distribution of selected algae and invertebrates from 1/16m^2 quadrat collections

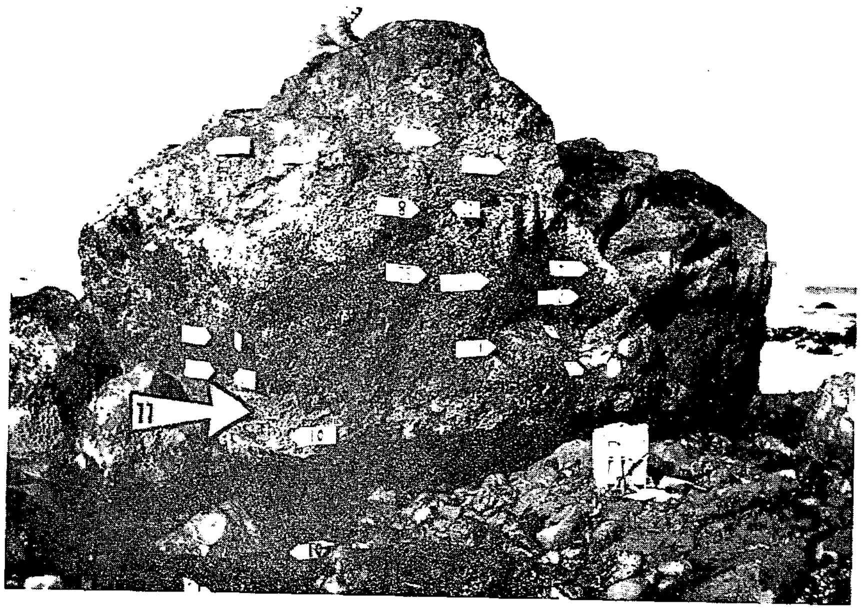


Fig. 21. Shoreward side of large boulder sampled by the arrow method. This was the heaviest biotic cover found at the site. Taken in April 1975.

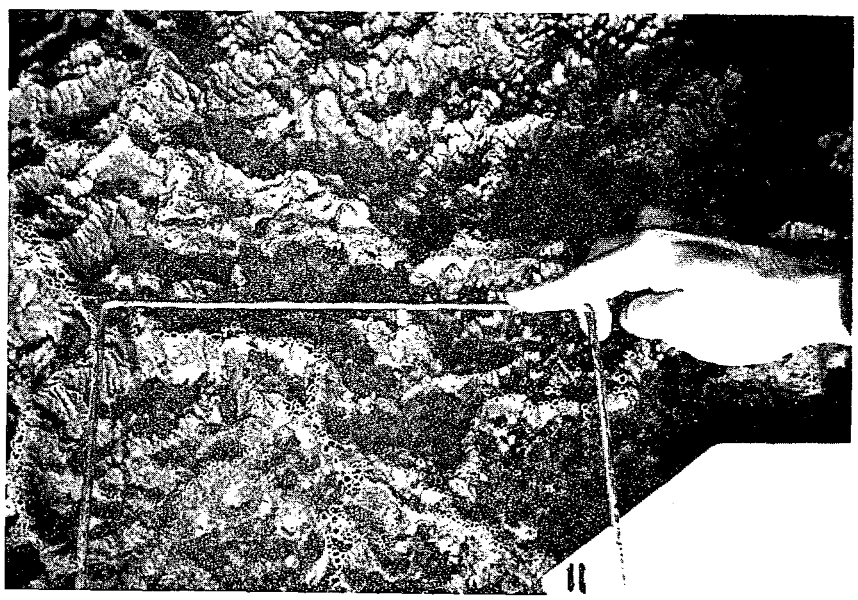


Fig. 22. Sponge cover at arrow II, at +0.5 feet (0. 15m) Taken in April 1975.

The abundance of macroflora and macrofauna was generally low on the boulder beach. In October 1974 we established a grid among cobbles and boulders in the *Fucus* zone and sampled it randomly (Table 1). The conspicuous organisms of this zone, *Fucus distichus* and *M. edulis,* differed in frequency of occurrence, but were both low in biomass. *Fucus* occurred in all quadrats and averaged 23.2 gm per quadrat (range, 0.2 - 42 gm per quadrat). *Mytilus* occurred in only 40% of the quadrats and averaged 35 gm per quadrat (range, 0.2 - 119 gm per quadrat) in those quadrats in which it was found.

In April 1975 we established three transects at Katalla (Table 1). Transect 1 was laid on the boulder beach in an area similar to that randomly sampled in October 1974. The results revealed a situation similar to that recorded in October. *Fucus* occurred in 62% of the quadrats at a relatively low biomass ($\bar{x}$ = 58.6 gin). *Mytilus* also showed a low biomass ($\bar{x}$ = 3.5 gm/quadrat; range, .002 to 10.7 gm/quadrat), but occurred more frequently (88% of quadrats) on the transect than on the grid.

Transect 2 was placed in the lower intertidal area of the boulder beach. Twenty-four species of algae and 47 species of animals were recorded in samples from this transect, but biomass 'here as at higher levels was low. *Laminaria groenlandica* showed the greatest biomass (up to 100 gm/ 1/16 m^2); other species of algae usually totaled less than 10 gm/quadrat, and were often too small to identify. The animals were mostly minute crustaceans (e.g. caprellids) and worms.

Transect 3 was placed across a large (12 m diameter) tidepool ranging in depth from a few inches to over a foot in the upper intertidal area. The bottom was covered with small boulders and cobbles which had a 50-80% cover of encrusting corralling algae. In addition there were occasional *Laminaria* plants (mean wt. 114.8 gm per 1/16 m^2) and scattered individuals of other species of algae. _Mytilus_ abundance averaged 1.2 per 1/16 m^2 (range, 1-6 per 1/16 m^2 its frequency of occurrence was 67%. One _Nucella lamellosa_ was recorded. The small herbivorous gastropod, _Lacuna marmorata_, was common throughout the pool (mean number, 155.5 per 1/16 m^2).

Our data indicate that potential ecological dominants (e.g. _M. edulis_) occupied only a small portion-of available space on the boulder/cobble beach. We can think of two types of physical disturbance that could account for this anomalous situation. The first results from frequent, heavy wave action which causes the cobbles and small boulders to roll around and collide constantly creating bare space and preventing competitive dominants from establishing large populations.

The second mechanism involves scouring of the boulder/cobble substrate by water-borne sand from the surrounding sand beach. This mechanism is less likely because large boulders (Fig. 21) adjacent to sand showed heavy biological cover, and quite low quantities of sand were seen in the boulder/cobble area. Our data are inadequate for distinguishing between these two mechanisms with confidence.

Sand Beach Study Sites

The four beaches (Hook Point, Big Egg Island, Kanak Island, and Softuk Bar) described below can be characterized as low-gradient sand beaches, exposed to the oceanic conditions of the Gulf of Alaska, They form part of a chain of such beaches and islands which stretch from Hinchinbrook Island across the Copper Copper River Delta to Controller Bay (Fig. 1). On these beaches physical factors such as small grain size, instability of substrate, and wave action, influence the scope of biological activity.

We visited each site once, in April 1976, and sampled it with transect lines extending from low tide to the drift zone (Table 1). One-liter core samples were collected at various intervals along the lines, both at the surface and below it; the deepest samples extended to a depth of 20 cm. The sand from haphazard cores and trenches dug with shovels was sieved with a 1 mm screen. A species list for each site (Appendix 2) was compiled from this sample data supplemented by visual observations. The composition and amount of accumulation of drift was noted,

At the western end of the chain, Hook Point forms part of a bedrock headland projecting into the Gulf of Alaska on the southeastern shore of Hinchinbrook Island (Fig. 1 and Sears and Zimmerman 1977, Plate EG-24). A small cove (lat. 60° 20' N, long. 146° 15'W) to the west of Hook Point was sampled (Fig, 23). The intertidal zone consisted of a wide sandy beach gradually sloping at a 1% grade. Running parallel to the shoreline were shallow troughs, apparently formed by wave action, containing standing water.

Eteone longa, a mysid, and a few unidentified Forminifera, nemerteans, and polychaetes were the only organisms present in our samples (Appendix 2). These occurred in the tidal range -.8 ft (-0.3 m) to +1.1 ft (+0.3 m), mainly in one area of standing water. One amphipod was collected at a higher tidal level. There was virtually no accumulation of drift.

Big Egg Island (lat. 60° 22'N, long. 145° 44'W) (Figs. 1, 24 and Sears and Zimmerman 1977, Plate EG-23) is the largest of a group of sand bar islands. Colonies of nesting gulls occur on the islands. Two transects each 60 m long were sampled and several trenches dug. Three live amphipods, Eohaustorius washingtonianus copepods, Calanus plumchrus, and two polychaetes, Thoracophelia sp. were found (Appendix 2). Drift consisted primarily of razor clam shells. Although we found no live clams, the area is indicated as supporting a razor clam population in the intertidal and nearshore subtidal regions (Anonymous, 1976, Fig. 18, p. 169).

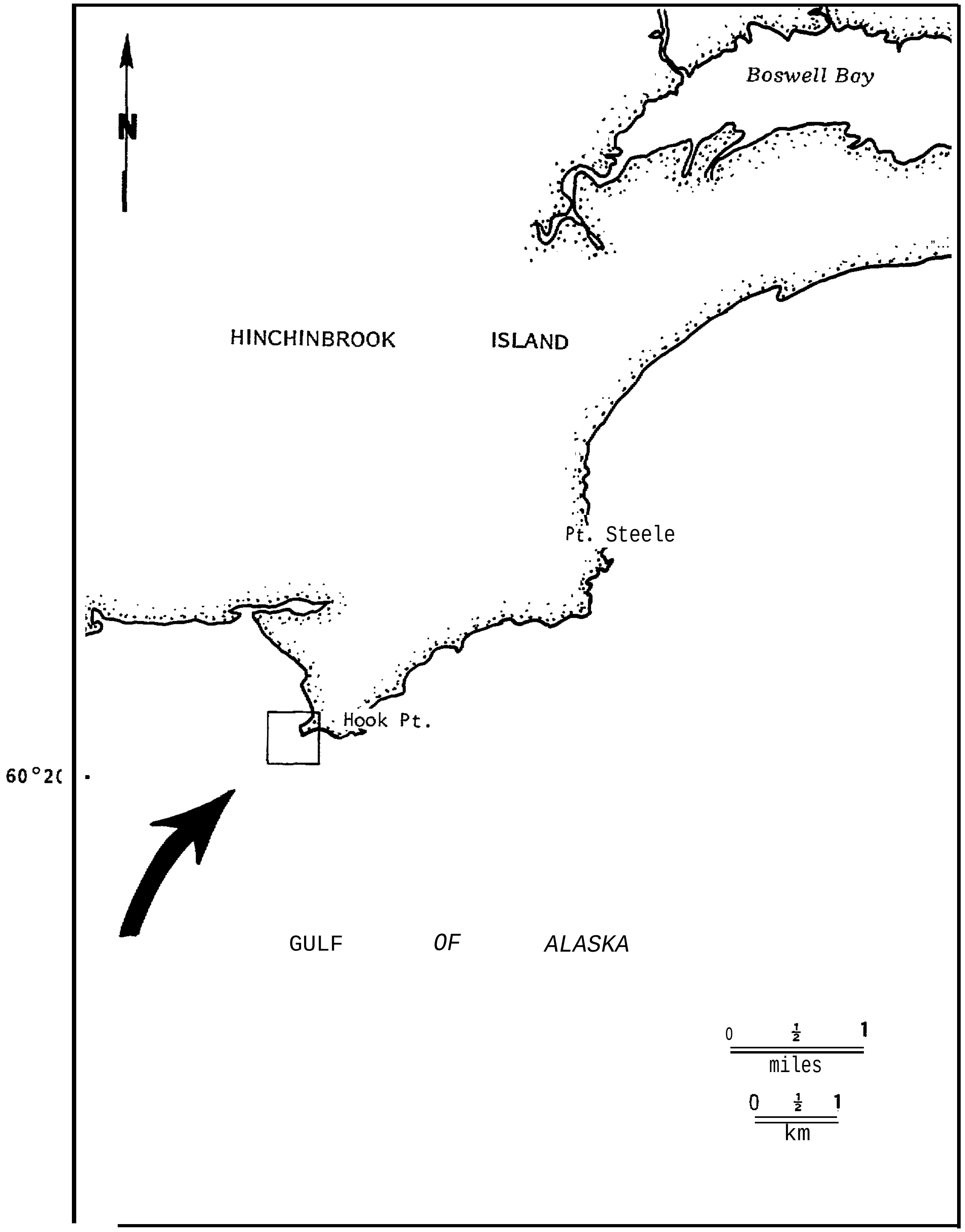


Figure 23 . Hook Point site.

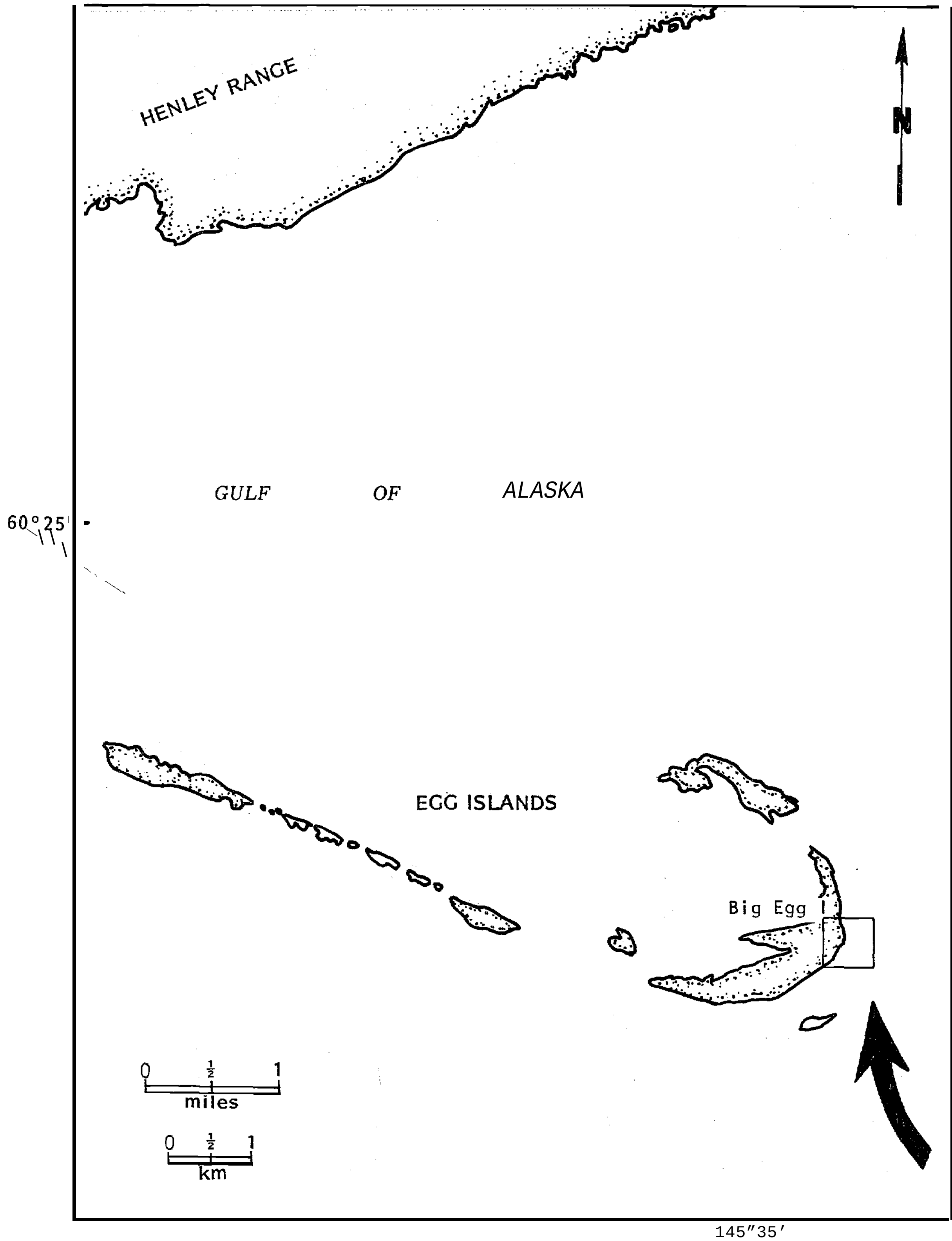


Figure 24. Big Egg Island site.

The Kanak Island site (lat. 60° 7.5'N, long. 144° 20'W) is locatedon the southeastern side of the island (Figs. 1, 25 and, Sears and Zimmerman 1977, Plates EG-19 and EG-20). The beach is approximately 270 mwide and flat. The substrate changed from muddy sand at the lowend of the transect (+2.3 ft to -0.3 ft) to loose sand at elevations up to +6.3 ft (+1.9 m) at the high end. This site supported the largest diversitv and biomass of organisms of the four beaches sampled (Appendix 2). Dominant organisms (in terms of biomass) were polychaetes (nine species and the bivalve, Macoma balthica. Nephtys SPP, Scoloplos armiger and Eteone longs were found over the entire tidal range. Excluding these species, species composition appeared to change with substrate composition. The greatest diversity of organisms was found at the muddy, low tidal levels. Red and green algae and gammarids were found only at these levels. Numerous unidentified castings were seen there.

At the sandy, upper levels, both the number of higher taxa and species within each taxon decreased. Macoma balthica was found from +3.0 ft (+0.9 m) to +6.3 ft (+1.9 m), the highest level sampled. Nematodes and the cumacean, Lamprops sp. also appeared in small numbers in this area.

Softuk Bar extends about 3 miles into the Gulf west of Katalla Bay (lat. 60° 12'N, long. 144° 42'W) and forms the eastern end of the chain of bars off the Copper River Delta. (Figs. 1, 26, and Sears and Zimmerman 1977, Plates EG-20 and EG-21). An extensive shallow muddy lagoon is enclosed by the bar and the mainland to the northeast. The southern side of the bar is sand. Samples were taken on the sandy side. Shifting surface sand contained only a few individuals of four species, Archaeomysis grebnitzkii, Emplectonema gracile, Eteone longa, and Eohaustorius washingtonianus. The packed sand layer beneath yielded only amphipod fragments. One razor clam shell and one crab fragment were found as drift.

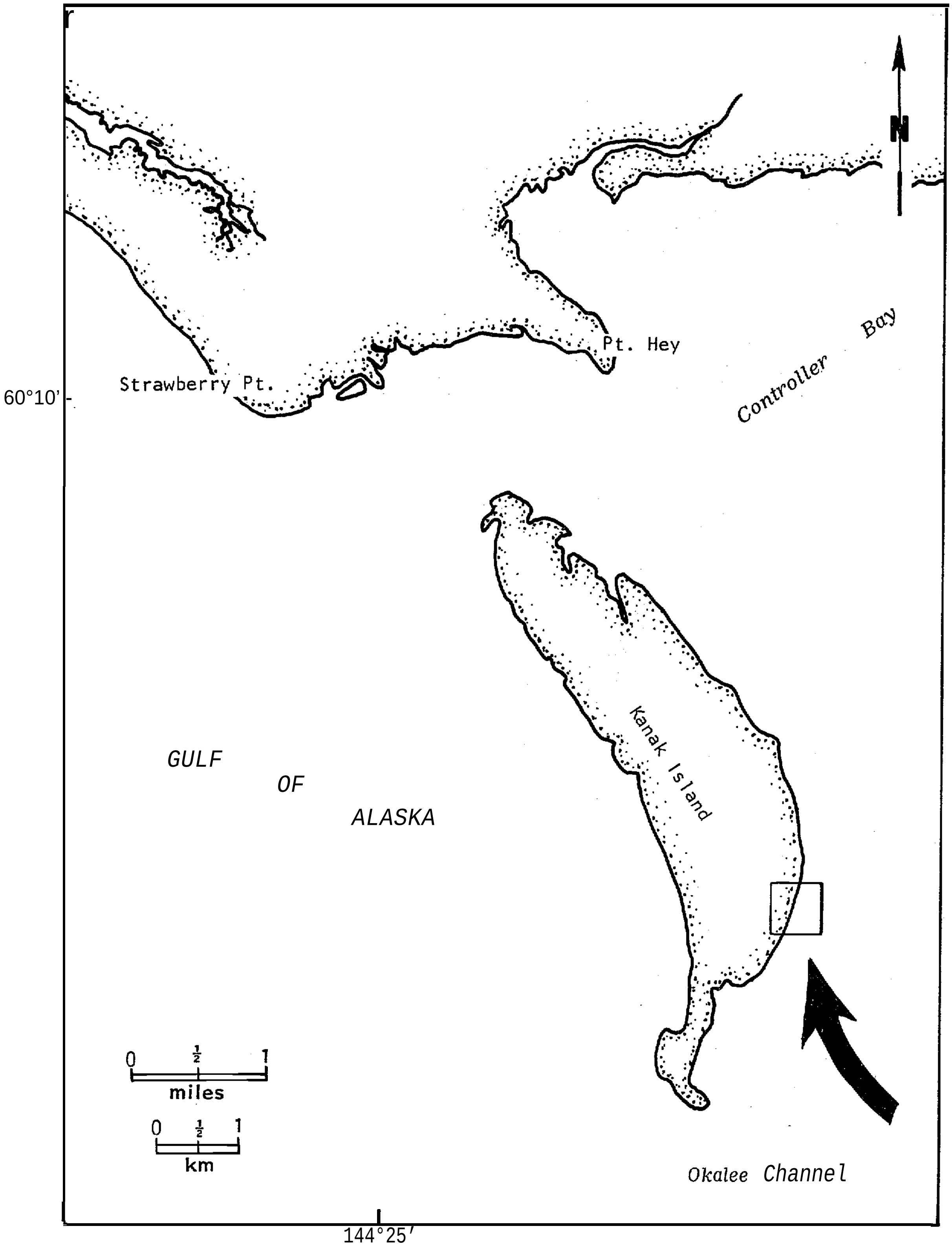


Figure 25. Kanak Island site.

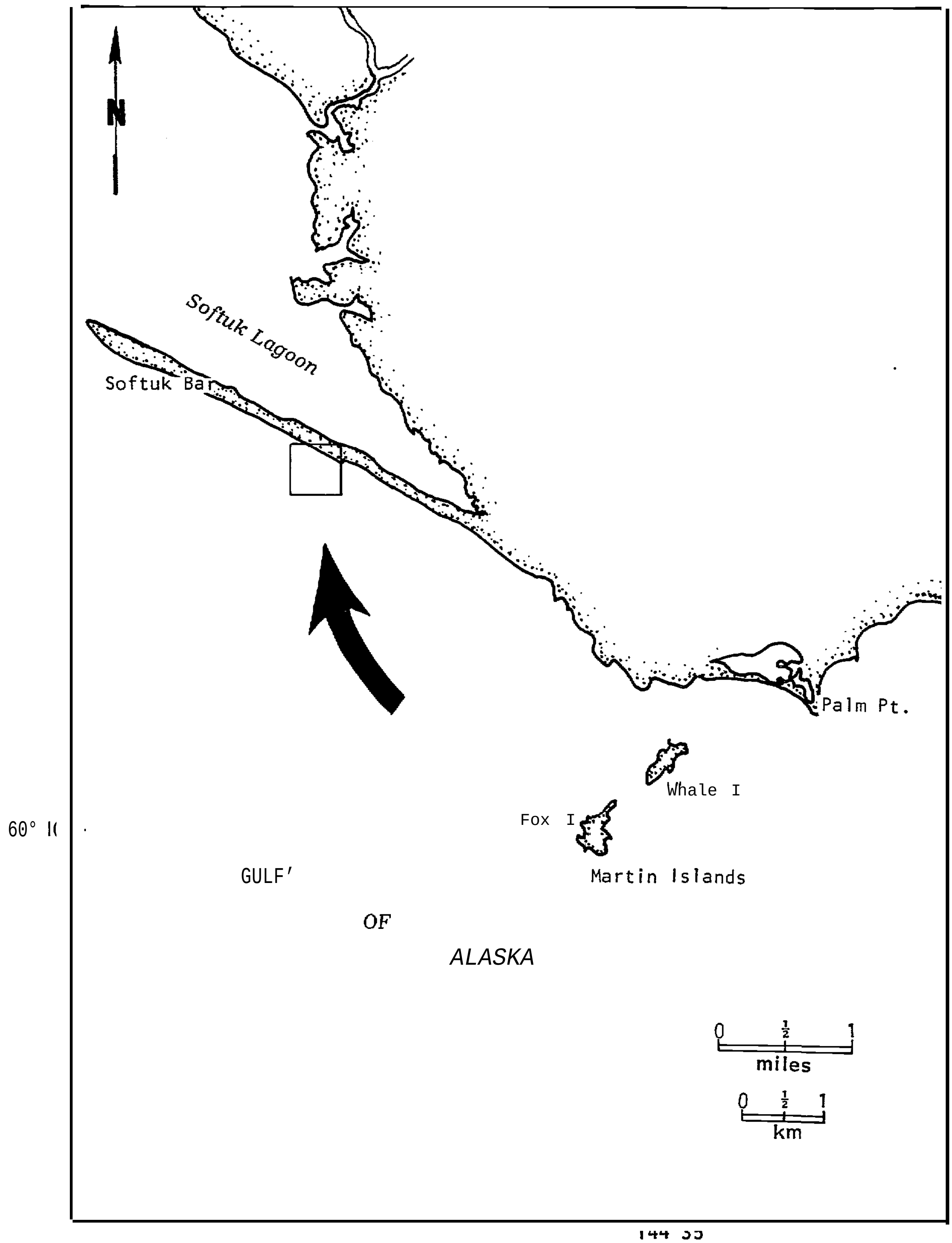


Figure 26. Softuk Spit site.

BOSWELL BAY

Location and Physical Description

Boswell Bay is an estuary indenting the eastern end of Hinchinbrook Island (lat. 60°24"' 36"N, long. 146°6′ 18"W) (Fig. 1). A large part of the bay is shoal with mud (Sears and Zimmerman 1977, Plate EG-24). Its entrance is a narrow channel in which tidal currents of two knots have been reported (Anonymous 1964). The site sampled is on the north shore, just inside the entrance (Fig. 27) with a monolithic rock island just offshore (Fig. 28) which can be reached from the sampling site by wading at low tide. In September silt was suspended in the water and covered the rocks (Fig, 29). Surface salinity was 13.9 ppt. Most sampling was done on a gravel-sand-mud beach (Fig. 28). Some additional work was done on a large rock nearby (Fig. 30).

Dominant Organisms

On rock throughout the intertidal zone *Balanus balanoides* and *B. glandula* formed the heaviest cover, in some areas approaching 100%, *Mytilus edulis* formed heavy cover only in patches, and were often themselves covered with barnacles. As would be expected at a low-salinity, estuarine site, there were no *B. cariosus* or echinoderms (urchins or starfish). Seaweeds were notably sparse. For example, *Fucus distichus* was present in only one of 20 1/16 m^2 arrow quadrats on rock ranging from +0.8 ft (+0.3 m) to +8.5 ft (+2.5 m) (Fig. 30).

On the mud beach, the most numerous species were the small clam. *Macoma balthica*, and oligochaetous worms which in September 1974 numbered as many as 213 and 476 per sample (1 liter) respectively. Fig. 31 shows the distributions of some species in September 1974. The clam *Mya arenaria* was present, but our quadrat size (1 liter) was too small to sample it adequately.

Mud core samples were taken in September 1974, May 1975, September 1975 and April 1976. The samples taken during the last three periods were

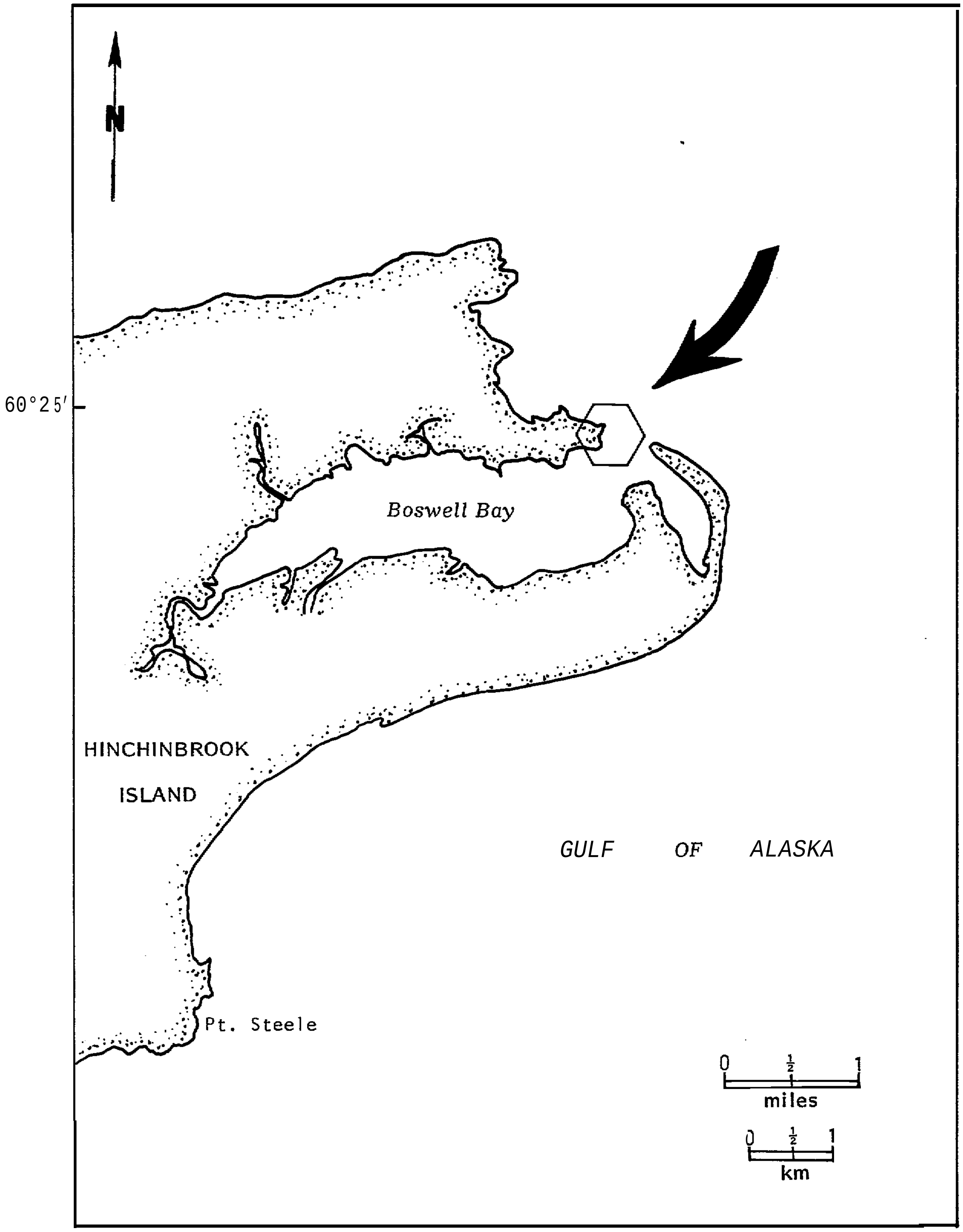


Figure 27 . Boswell Bay site.

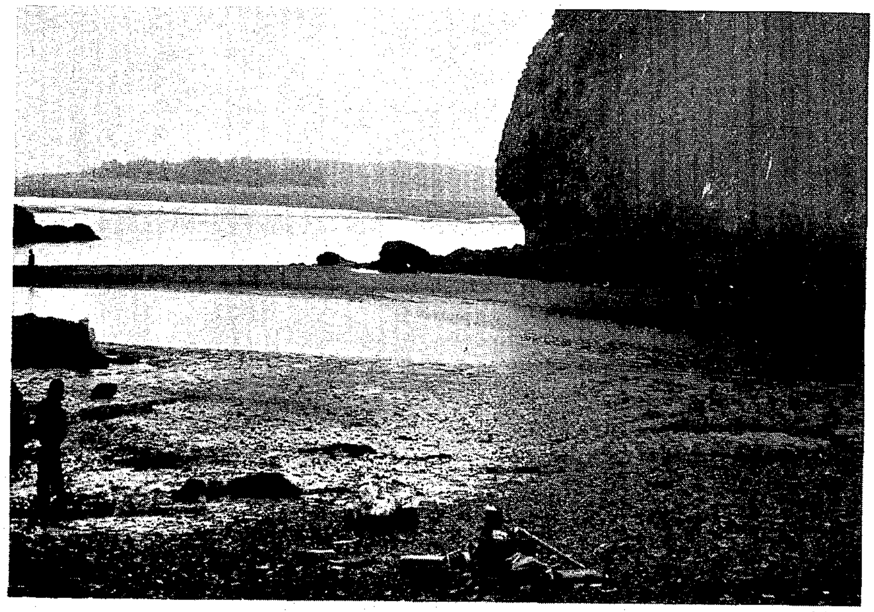


Fig. 28. Mud and gravel beach at low tide showing off-shore monolith. Taken in September 1975.

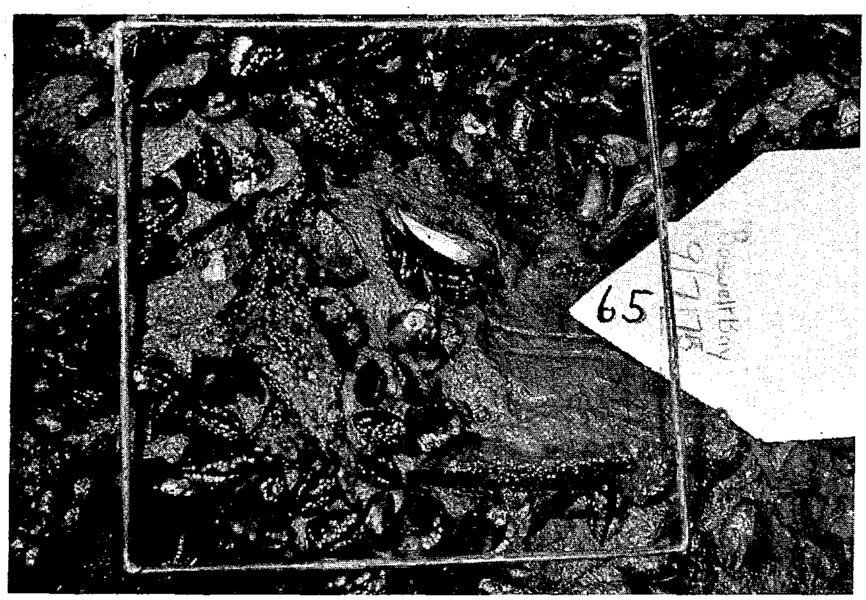


Fig. 29. Arrow 65 on lower part of rock. Note heavy silt deposit between mussels and barnacles on mussel valves, Taken in September 1975,

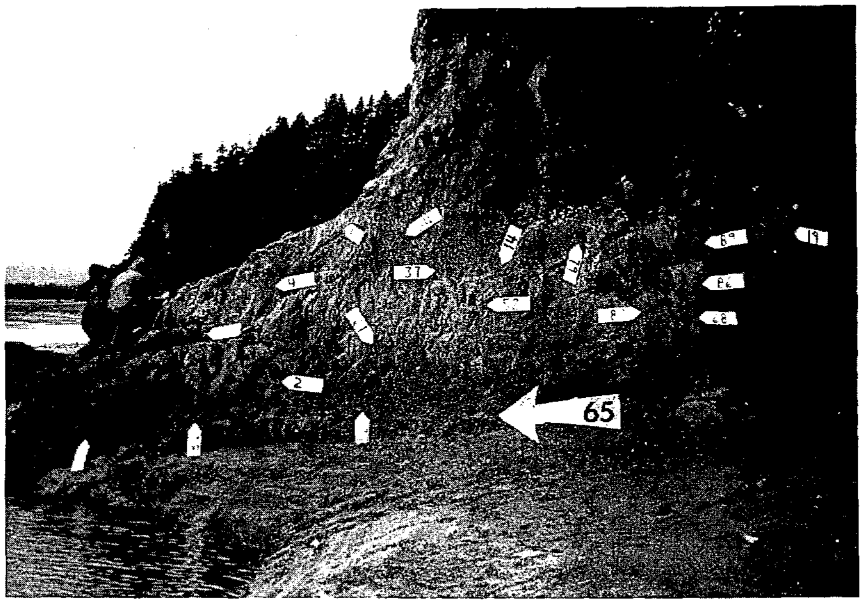
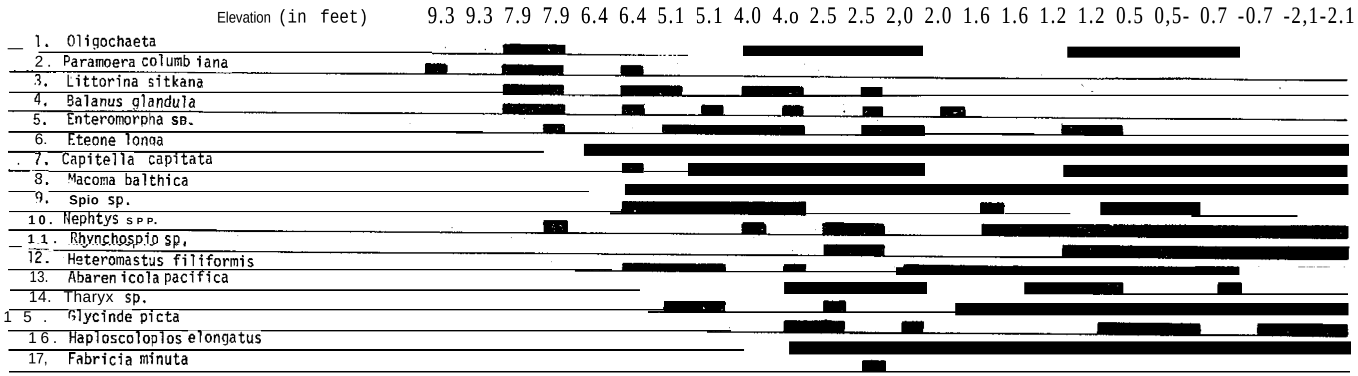


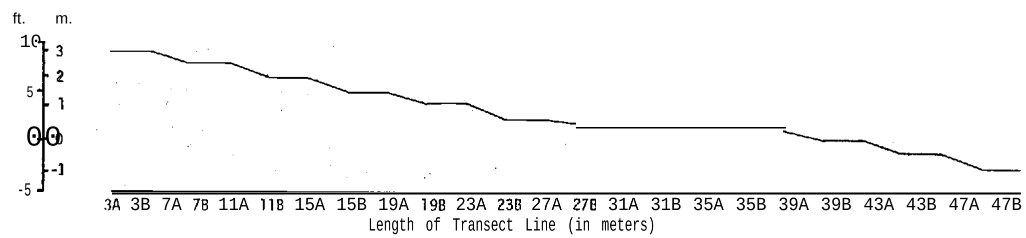
Fig. 30. Arrow site with heavy barnacle cover above and patchy mussel cover below. Taken in September 1975.

Boswell Bay
Intertidal Station 6
September 1974 Transect. 1



Fig, 31

Horizontal and vertical distribution of selected algae and invertebrates from 1/16 m^2 quadrat collections along a transect line.



not adequately fixed, and soft bodied, delicate organisms, especially polychaetes, fragmented and passed through our sieves.

MIDDLETON ISLAND

Location and Physical Description

Middleton Island (lat. 59° 25.2'N, long. 146° 22.5'W) is a low (elevation 125 ft (38.4 m)) island (Fig. 32) in the northern Gulf of Alaska, about 50 mi (92.6 km) south of the entrance to Prince William Sound (Fig. 1). The island is fringed with reefs, rocks, and heavy kelp to a distance of 0.4 mi (0.7 km). Breakers occur at greater distances. The island was uplifted 15 to 20ft (4.6 to 6.1 m) in the 1964 earthquake (Anonymous, 1964). The sampling area, (Fig. 33 and Fig. 34), is a mudflat strewn with boulders. We collected 10 l-liter cores in October 1974 and in April 1975, and 9 cores in September 1975.

Dominant Organisms

Four polychaete worms, Abarenicola pacifica, Capitella capitata, Rhynchospio sp., and Pygospio sp., were abundant in all seasons. Nereid worms, Nereis procera, Nereis vexillosa, and Nereis sp. were collected only in the fall. Although algal fragments, insect larvae, amphipods and other marine invertebrates are represented in the collections, polychaete worms are the dominant group, and Abarenicola pacifica is the most conspicuous (Appendix 3). Several species of shore birds, ducks, and geese were observed feeding and resting in this area in September 1975.

The boulders throughout the area, almost to the water's edge, have Fucus distichus, Littorina sitkana, and Balanus sp. growing on them. A large aggregation (thousands) of Littorina sitkana was observed high on the beach. Large limpets, probably Notoacmea persona, were common. Mussels (Mytilus edulis) were very sparse and were found on boulders close to the water's edge. Filamentous green algae, Porphyra sp., and colonial diatoms were also found on

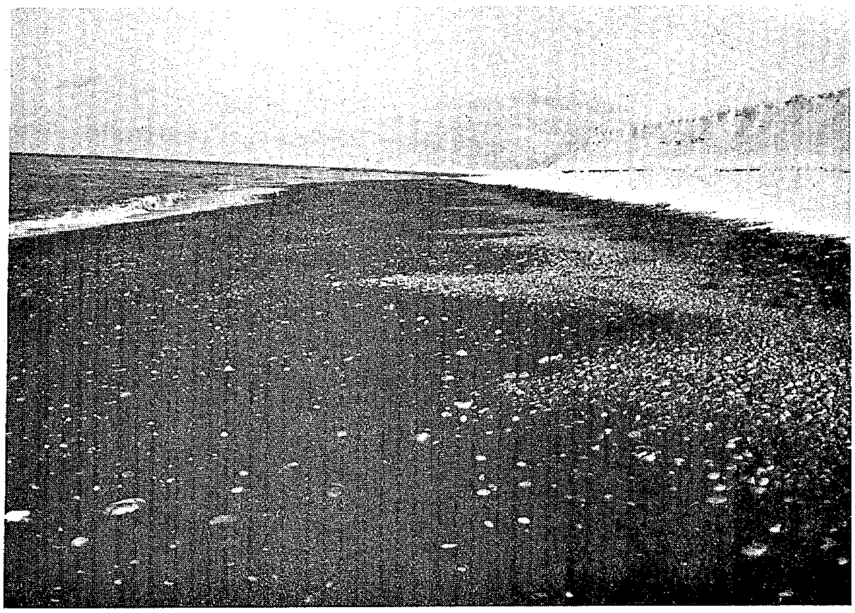


Fig. 32. Middleton Island showing low bluffs and sand beach. Taken in December 1975.

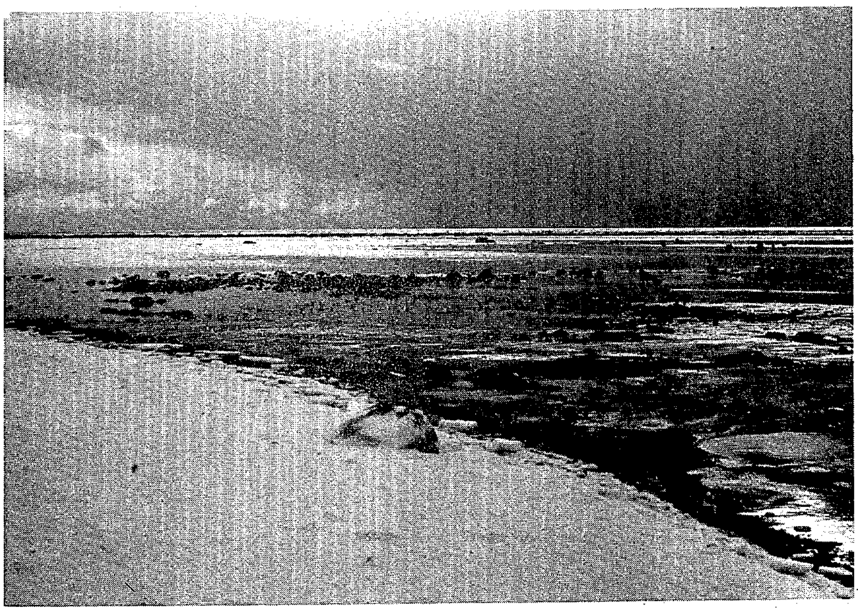
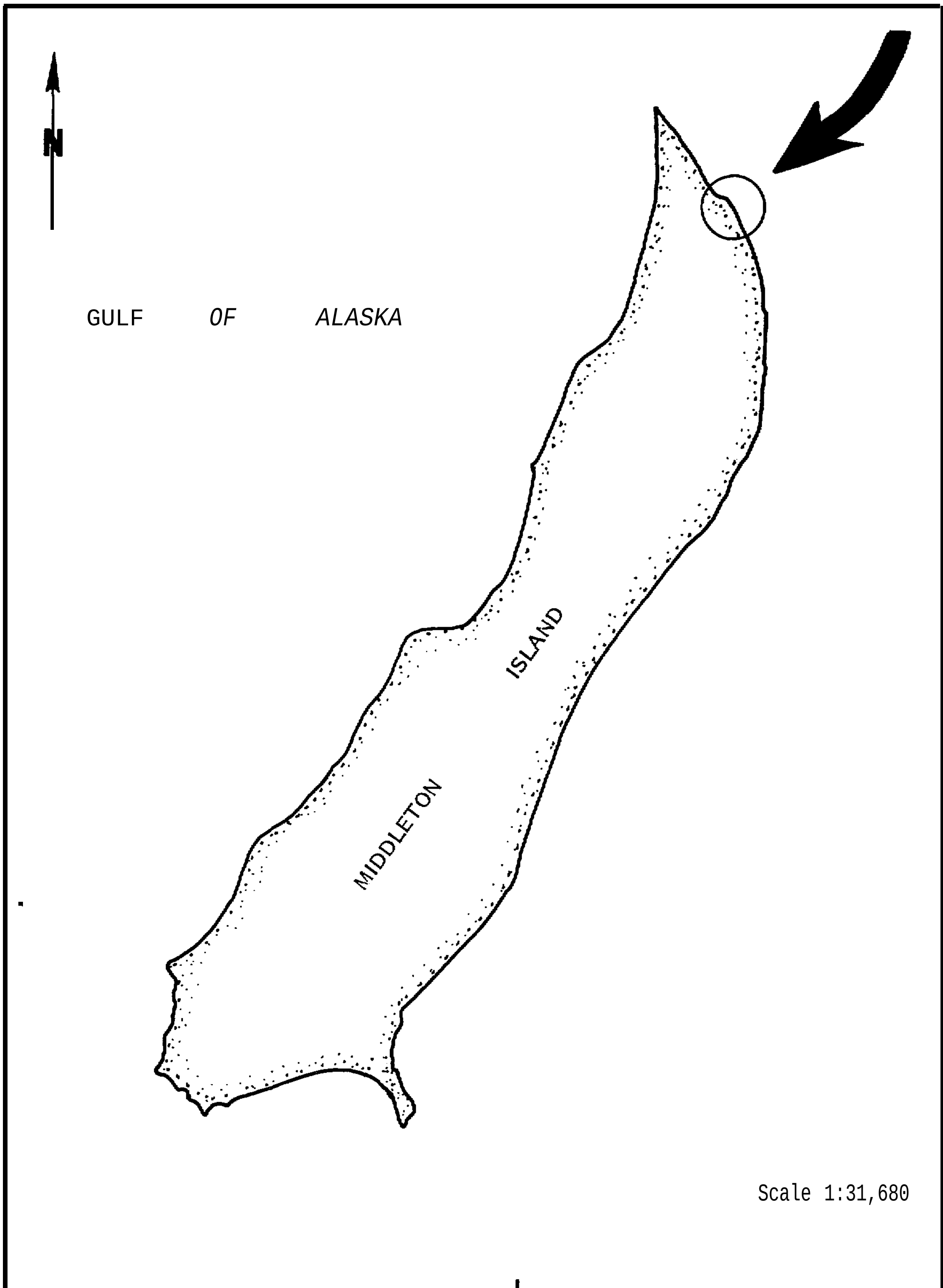


Fig. 33. Middleton Island sampling area. The beach is mud and boulder, extending about 0.5 mi to the water. Taken in December 1975.



59° 26

146° 20′

Figure 34. Middleton Island site.

boulders. *Rhodomela larix* and *Bossiella* sp. were found in standing water. *Laminaria* sp. was observed growing on boulders in pools at the outer edge of the beach. Several species of algae, mostly *Nereocystis lutkeana* and *Palmaria palmata*, were found in the drift. Shells of *Mytilus californianus* were also present.

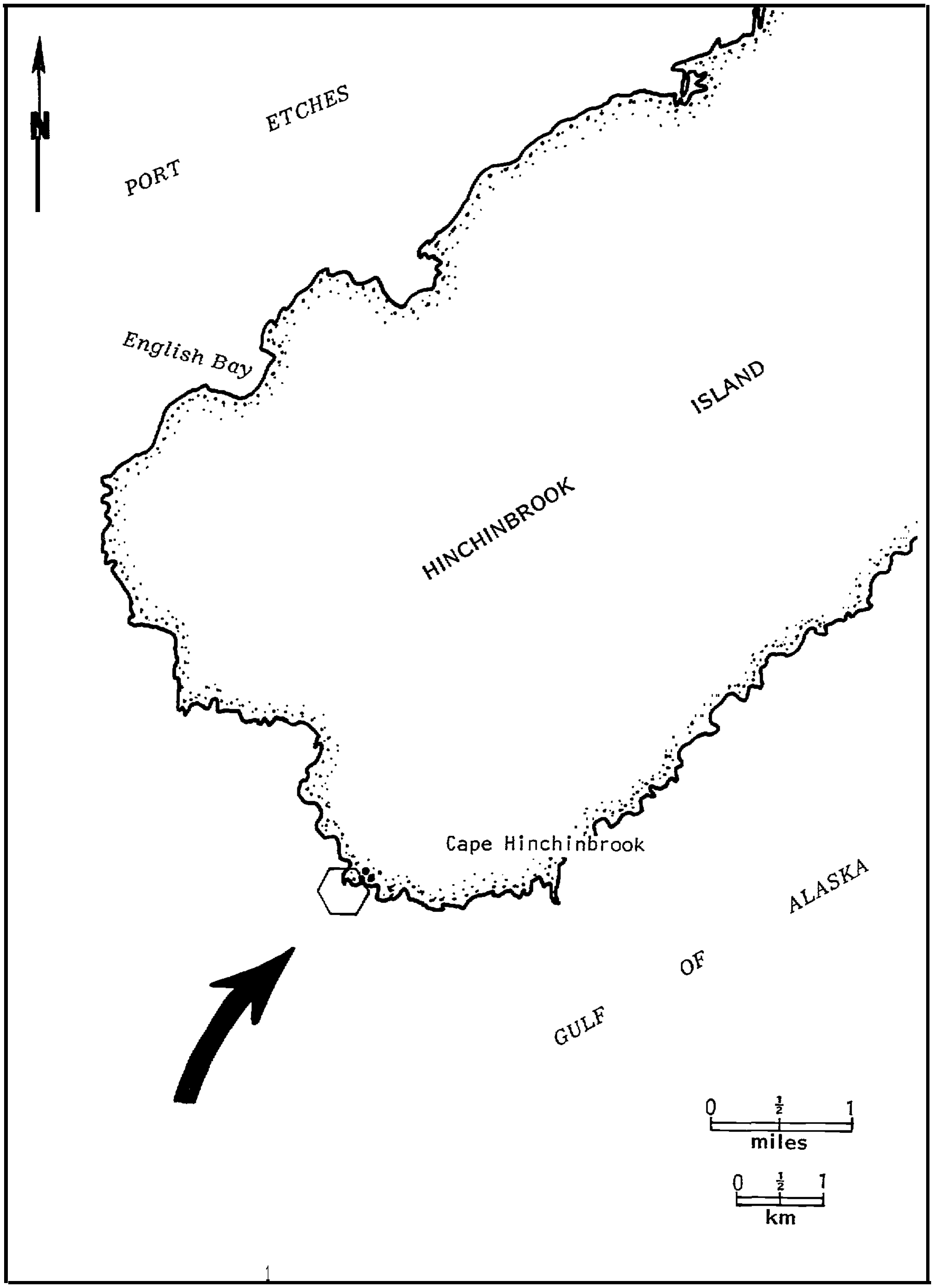
CAPE HINCHINBROOK, HINCHINBROOK ISLAND

Location and Physical Description

Cape Hinchinbrook (lat. 60° 14.3'N, long. 146° 38.8'W) is on the southernmost tip of Hinchinbrook Island, on the eastern side of Hinchinbrook Entrance (Figs. 1 and 35). The Cape juts into the Gulf of Alaska and in a southerly gale is subject to heavy wave action. During our sampling period in April 1976, wind and storm surge pushed the tide high on the beach.

There are steep cliffs above the beach (Fig. 36). Cape Hinchinbrook light is located on the cliffs above our site and is 235 ft (71.6 m) above the water (Anonymous 1964). The beach is bisected by a small fresh water stream. We made qualitative observations along two transects, one to the west (transect 1) and one to the east (transect 2) of the stream. Transect 1 is in an area of sedimentary bedrock which has been tilted so that the layers are vertical. The bedrock surface is strewn with numerous large (0.5 to 3 m on a side) chunky, often flat-topped boulders and small cobbles (Fig. 37). Transect 1 was 40 m long, and extended from the -0,4 ft (-0.1 m) to the 11.4 ft (3.5 m) tidal level. Transect 2 is similar to transect 1 but with the bedrock substratum rising abruptly from the water line along a short near-vertical face and then continuing in a series of hummocks to the base of the cliffs. The boulder field is more dense than along transect 1 and the average size of the boulders is smaller (Fig. 38). There are several small tidepools along the transect and an area of fresh water runoff near the upper end of it. Transect 2 was 46 m long and spanned the tidal levels +0.4 to +10.6 ft (0.1 to 3.2 m).

60°1!



146°40'

Figure 35. Cape Hinchinbrook site.

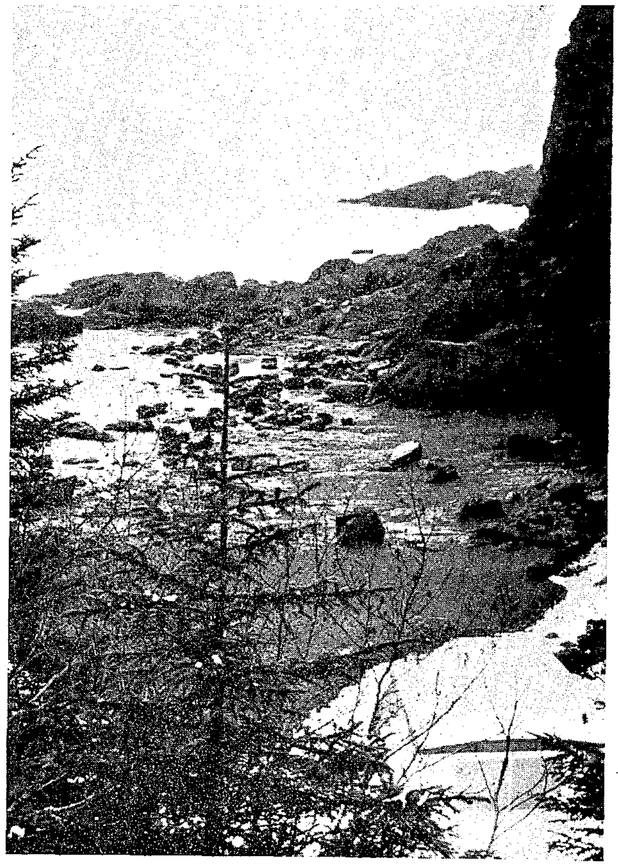


Fig. 36. View of sampling site at Cape Hinchenbrook showing general location of transect 1. The beach consisted of boulders on low gradient bedrock rising abruptly to a steep cliff. Taken in April 1976.

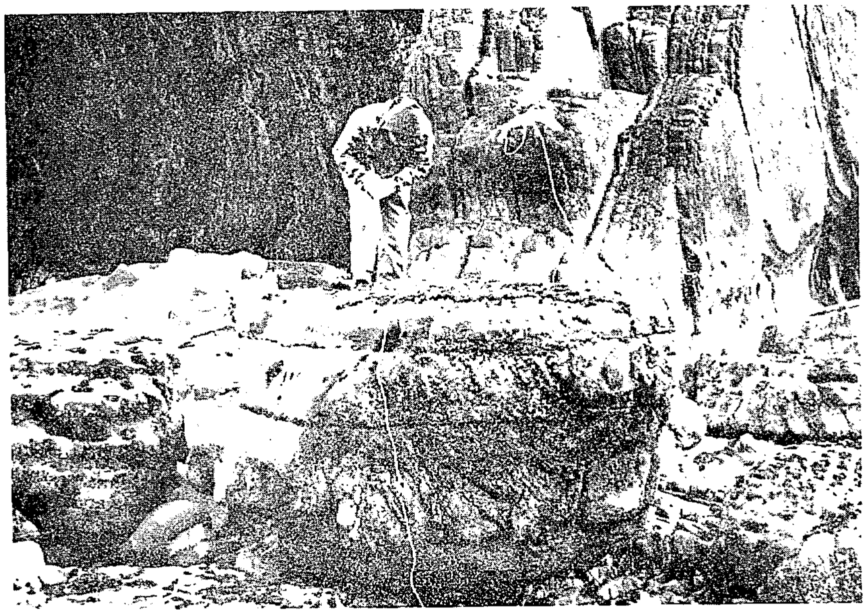


Fig .37. Upper end of transect 1 showing tilted bedrock and large chunky boulders. Taken in April 1976.

Fig. 38. View along transect 2 showing boulders and hummocky bedrock. Taken in April 1976.

Dominant Organisms

Transect 1 (Fig. 37): Palmaria palmata (=Rhodymenia palmata) was the dominant macrophyte along transect 1, observed in 26 of 40 quadrats. It occurred with 100% cover in three quadrats falling on a slow-draining bedrock bench, a favored habitat (Lewis 1964). A heavy coating of diatoms was observed in 13 quadrats. Endocladia muricata also occurred in 13 quadrats, most of them in the high zone. Gigartina papillata occurred in 11 quadrats. Porphyra spp. was observed in 10 quadrats; one species occurred in small amounts in the mid-zone, and a second species was confined to the +11.4 ft (+3.5 m) level where it covered the entire quadrat. Fucus distichus was sparse; it occurred in only six quadrats and percent cover was <10. Balanus sp. was the animal with the highest relative frequency along transect 1. It occurred in 27 of 40 quadrats, but percent cover was generally low. Unidentified limpets were present in 15 quadrats. In the low zone they occurred singly or in small numbers and were about 1 to 3 cm in length; in the high zone they were generally small (5 mm) and were clustered in small depressions or crevices. Mytilus edulis was observed in 14 quadrats; most of these mussels were small (<1.5 cm) and were attached to sprigs of algae, on barnacles, or in rock crevices. Predators were rare; two Leptasterias hexactis were seen at the +1.7 ft. (0.5 m) level, and three Nucella lima were seen at the +4.8 ft (1.5 m) level. A cluster of N. lima was seen adjacent to those in the quadrat; none of them were feeding.

Transect 2 (Fig. 38): Palmaria palmata was the dominant algae in the low zone and Fucus distichus and Endocladia muricata were dominant at higher elevations. Macrophyte cover was light. Barnacles (mostly Balanus glandula) occurred most frequently, but percent cover was low, and there were several scars of dead barnacles. Coralline algae, small plants of Alaria sp. and Laminaria sp., sponge, anemones and Pagurus sp. were found in tidepools.

Unidentified limpets and the littorine snails, Littorina sitkana and L. scutulata were common. Predators were uncommon; one Leptasterias hexactis was found in the low zone, and Nucella lima was found in five quadrats. An aggregation of 30 N. lima (not feeding) was observed at about the +7 ft (2,1 m) elevation, but elsewhere only one or two N. lima were observed.

POINT BARBER, HINCHINBROOK ISLAND

Location and Physical Description

Point Barber (lat. 60° 19.8'N, long, 146° 39.5'W) marks the southwestern end of the northwestern shore of Port Etches, Hinchinbrook Island (Figs. 1 and 39). The mid and lower intertidal region at Point Barber is a gently sloping bedrock platform, but the upper intertidal region has localized areas of vertical relief. (Fig. 40; see also Plate EG-26 of Sears and Zimmerman 1977). Exposed rocks along a section of coast near the study area are "massive graywacke" alternating in stretches with "highly contorted thin bedded argillite and graywacke" (Moffit 1954). The bedding planes of the rock comprising the intertidal platform are strongly tilted. Point Barber is partially protected from open ocean waves and swells by the southwestern peninsula of Hinchinbrook Island and nearby Porpoise Rocks, but it probably receives severe wave shock during winter storms.

The area of Prince William Sound near Point Barber was uplifted in the range of 6 to 8 ft (1.8 to 2.4 m) during the Great Alaska Earthquake of 1964 (Fig. 1 of Haven 1971). In May 1977 we observed empty shells of the rock boring piddock, Penitella penita, partially protruding from the surface of the rock platform in the mid-intertidal zone among Fucus distichus and Mytilus edulis. These bivalves normally occur in lower intertidal and subtidal regions [although Evans (1968) has recorded P. penita as high as +0.6 m in the intertidal zone at Coos Bay, Oregon], and probably died when they were lifted above their

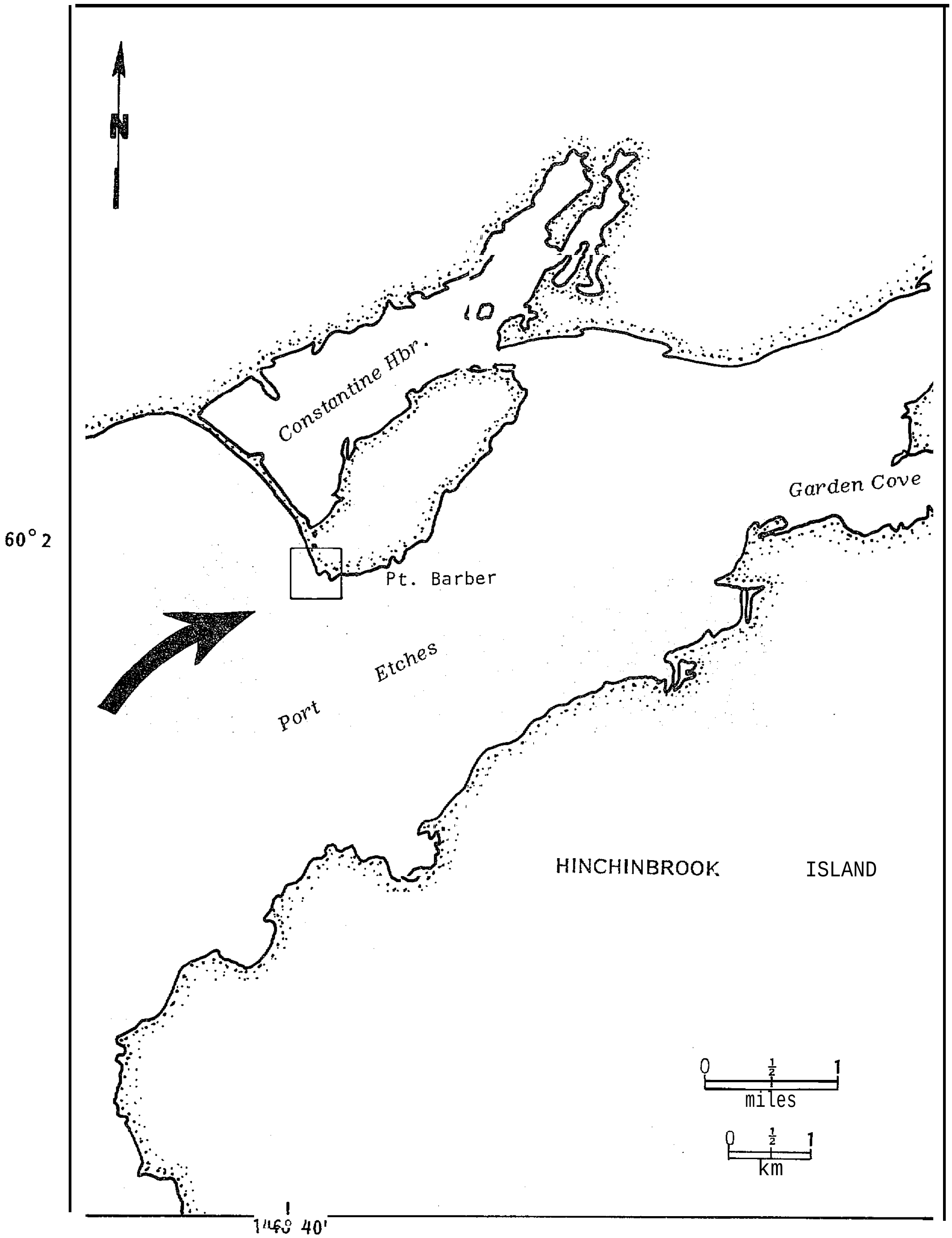


Figure 39 . Port Etches site.

Fig. 40. Oblique view of study area at Pt. Barber looking across Hinchenbrook Entrance to Montague Island. Taken on 7 May 1977 by C.E.O'Clair.

upper physiological limits by the earthquake. The empty shells are becoming gradually exposed as the surface of the rock platform erodes away.

Dominant organisms and community patterns

We made qualitative observations of intertidal communities in May and July/August, 1977. The upper and mid-intertidal zones were dominated by *Fucus distichus* with *Balanus* spp. (mostly *B. glandula*; *B. balanoides* was not recorded, but may have been present) dominant on rock outcrops above the *Fucus*. Although small *M. edulis* (mean shell length of 439 haphazardly collected individuals was 1.1 cm, SD 0.9 cm) were abundant in the *Fucus* zone in May, there were few large (shell length > 3 cm) *Mytilus* except in patches on the southeastern side of the site (Fig. 41). By contrast, in 1973 two of us (N. Calvin and J. Gnagy) noted that large *M. edulis* were abundant especially on the northeastern side of the point.

Pisaster ochraceus was common at Point Barber during both observation periods, but it was less obvious in May because many individuals were in tidepools hidden beneath over-hanging rock around the periphery of the pools. In July/August most *Pisaster* were plainly visible on the platform surface. Scattered individuals of *Nucella* sp. (*N. lima* or *N. emarginata*) and *N. lamellosa* were observed in upper and mid-intertidal zones.

Most of the lower intertidal platform was covered by *Palmaria palmata* and *Alaria* sp. (Fig. 42). A large number of *Alaria* were small (blade length 50 cm). *Rhodomela larix* was generally abundant in poorly drained areas in the upper part of the lower intertidal zone; *Phyllospadix* sp. occupied this type of habitat at lower levels.

Leptasterias hexactis was common throughout the mid and lower intertidal zones. One female was observed brooding eggs in May. Other starfish in the lower intertidal zone were *Evasterias troschelii* (rare, only one individual seen), *Dermasterias*

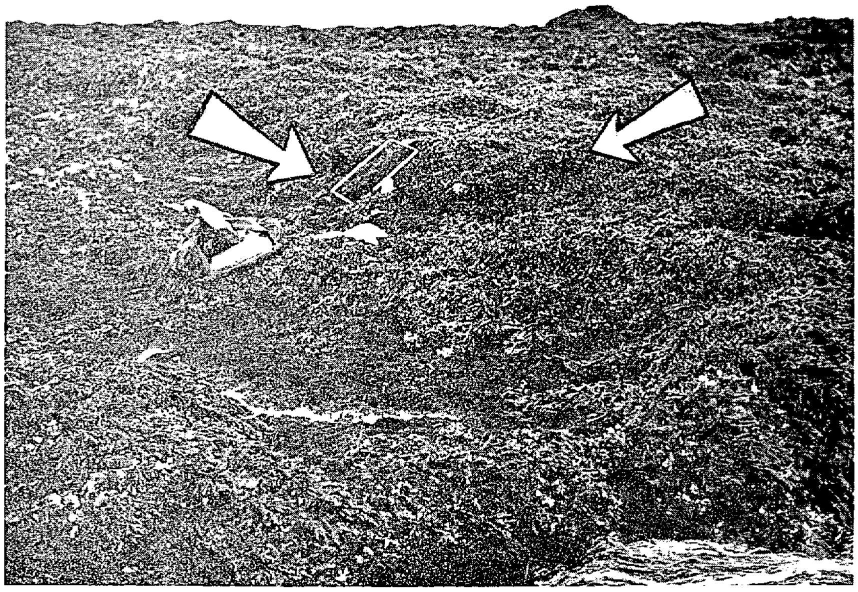


Fig.41. Patches of large Mytilus at Pt. Barber taken on 6 May 1977 by C.E. O'Clair.

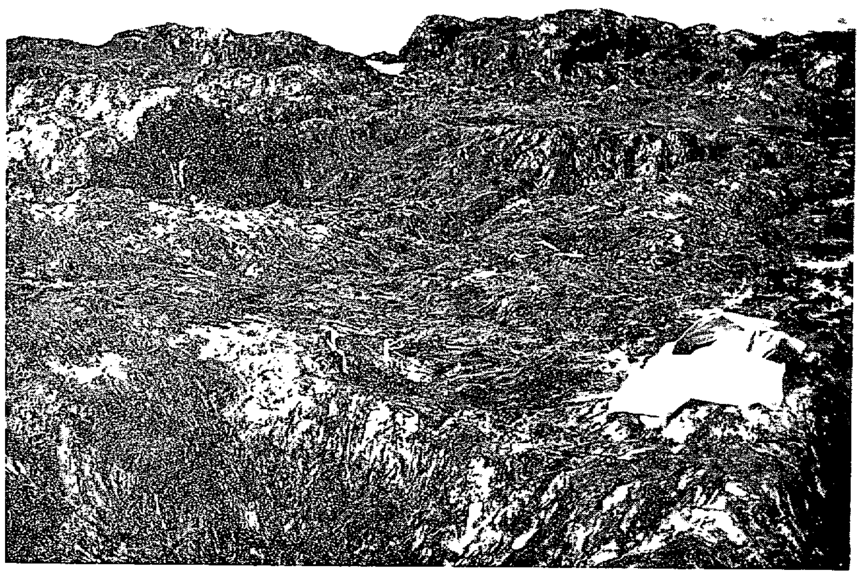


Fig.42. View of lower intertidal platform at Pt. Barber. Taken on 5 May 1977 by C.E. O'Clair.

imbricata, and Pycnopodia helianthoides.' Scattered individuals of Balanus cariosus were present throughout the mid and lower intertidal zones. Chthamalus dalli were numerous on ridges and hummocks near the seaward edge of the intertidal platform. "Large patches of the encrusting sponge Halichondria panicea accompanied by the nudibranch Archidoris montereyensis were abundant near the seaward edge of the platform (Fig. 42). In Washington 74% of the diet of A. montereyensis consists of H. panicea (Bloom 1974).

At the lowest reaches of the intertidal region and in tide pools the major canopy species. was Laminaria dentigera intermixed with a few L. yezoensis plants., Obvious invertebrates in these habitats were the. cnidarians Anthopleura elegantissima (in upper pools)" and Tealia crassicornis, an occasional decapod crustacean (Oregonia gracilis, Pugettia gracilis, or very rarely Placetron wosnesenskii), and a few small urchins, Strongylocentrotus droebachiensis.

Factors affecting community-structure

It is impossible to examine adequately the dominant factors that determine community structure by observing a community twice, but our descriptive studies at Point Barber suggest several factors that are likely to be important to community organization there.

Physical disturbance can be important to community structure. Theory predicts that frequent, severe, or chronic disturbance will reduce species richness, but infrequent and/or local disturbance can increase species richness by creating patches which competitively inferior species can colonize (Levin and Paine 1974). Dayton's (1971) study of the effects of wave-borne logs on intertidal community structure supports this theory. We noted evidence of recent physical disturbance at Point Barber, especially in May 1977, by the presence of patches of bare rock apparently created by erosion of large pieces of rock from the surface of the intertidal platform; other patches had apparently been cleared earlier since they were covered with foliose green algae (*Ulva* and/or *Monostroma*); both genera are rapidly growing and ephemeral, and frequently appear early on freshly cleared surfaces (Northcraft 1948, Dayton 1971, Lebednik and Palmisano 1977). Most recently disturbed areas are small and uncommon at Point Barber, and it does not appear that exfoliation of the bedrock surface is an important determinant of intertidal community structure there.

Another disturbance which could be important to biotic populations on the northwestern side of Point Barber is scouring by sand and gravel suspended in longshore currents from the beach northwest of the Point. The absence of adult *M. edulis* in this area may be a result of scouring, but predation by *Pisaster* (and possibly *Nucella*) (see below discussion} is a more likely cause because adults of other organisms (e.g. *E. distichus* and *B. cariosus*) which would have been removed by scouring by sand, gravel or ice were common. As stated above, the size and abundance of disturbed areas suggest that storm and log damage and freeze-thawing were not important structuring factors of the community at these levels at Point Barber.

Biological interactions, especially predation, have been shown experimentally to be important structuring agents in intertidal communities. Paine (1966, 1974) has shown that *Pisaster ochraceus* plays a dominant role in the structure of rocky intertidal communities on the outer coast of Washington by preying on *Mytilus californianus*, a species which dominates in competition for space. *M. edulis* reaches a smaller average adult size than *M. californianus*, but Menge (1976) has shown that *M. edulis* is capable of dominating the mid-intertidal region on horizontal and inclined surfaces in exposed and (in the absence predation by *Thais (Nucella)*) protected areas. In May 1977 adult *Mytilus* were abundant in but a few small patches on the southeastern side of Point Barber. One permanent 1/4 m^2 quadrat was placed haphazardly in each of three *Mytilus* patches in the upper intertidal and photographed in May. The quadrats were rephotographed in July. One plot showed a striking decrease in coverage (from 37% to 2%) in the interval from May to July (Figs. 43 and 44). Several *Pisaster* and empty shells and plates of *M. edulis* and *B. cariosus* respectively were near the plot in July. Predation by Nucella is an unlikely source of mortality of *Mytilus* at the plot because few were observed at Point Barber in May and July.

The patches of *Mytilus* were probably near the upper limit of *Pisaster*. Below these patches the intertidal bench gradually slopes to the sea; there are few drainage channels to allow *Pisaster* ready access to shoreward areas. Apparently these patches had been free from *Pisaster* predation for at least 2 to 3 years allowing *Mytilus* to attain a large size.

On the northwestern side of Point Barber adult *Mytilus* were scarce probably because of *Pisaster* predation since 1973. Large drainage channels give *Pisaster* access to shoreward areas of the bench here (Fig. 45). Dense coverage of young *Mytilus* indicate that the habitat is still suitable for the settlement and persistence of young *Mytilus*.

ZAIKOF BAY

Location and Physical Description

Zaikof Bay is a 2.5 mile wide embayment located on the northeastern end of Montague Island at the west side of Hinchinbrook Entrance to Prince William Sound (Fig. 1). The intertidal survey site is located on a rocky point (lat. 60° 17′ 54"N, long. 147° 00'00"W) on the south side of the Bay (Fig. 46and 47). The point is a moderately sloping bedrock reef extending northeasterly; slightly into the bay and consisting of several large bedrock hummocks separated by crevices. The point is bordered on the east by a gravel beach; to the west the beach rapidly grades from a medium boulder to a gravel substratum (Sears and Zimmerman 1977, Plate EG-29).

Fig .43. View of a quadrat in a patch of *Mytilus* at Pt. Barber. Compare with Fig. 44. Taken on 6 May 1977 by C.E. O'Clair.

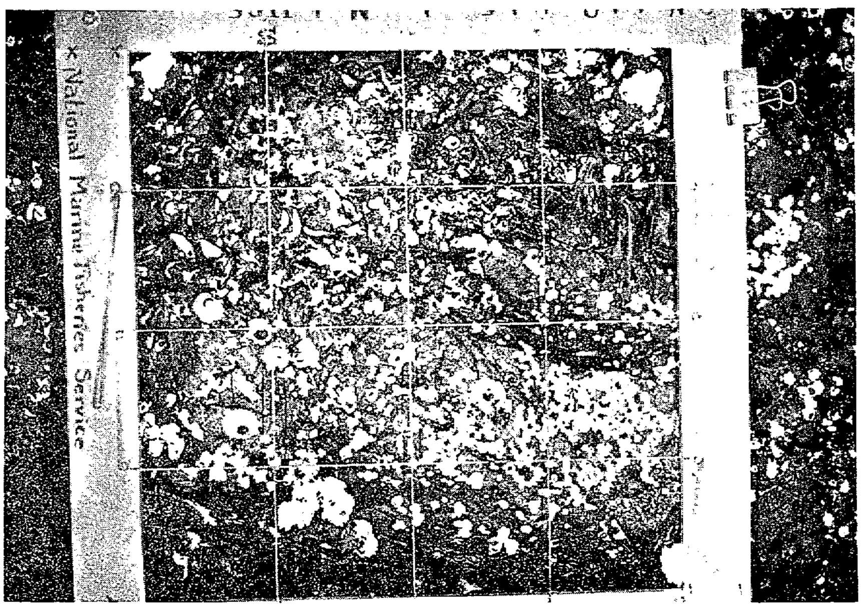


Fig. 44. View of a quadrat in an area formerly occupied by *Mytilus* at Pt. Barber. Compare with Fig. 43 . Taken on 31 July 1977 by C.E. O'Clair.

Fig. 45. View of drainage channel at northwestern side of Pt. Barber. Taken on 6-May 1977 by C.E. O'Clair.

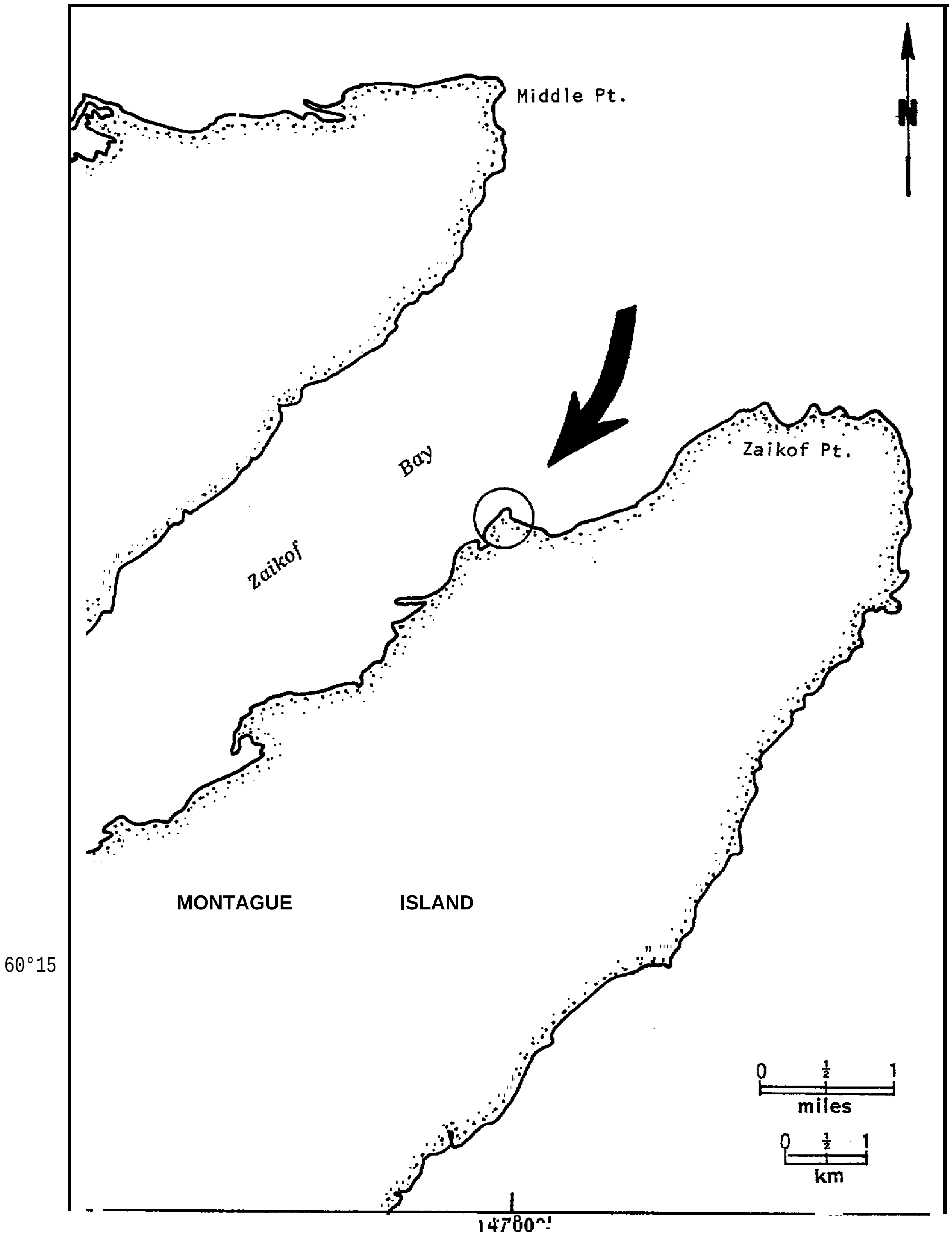


Figure 46. Zaikof Bay site.

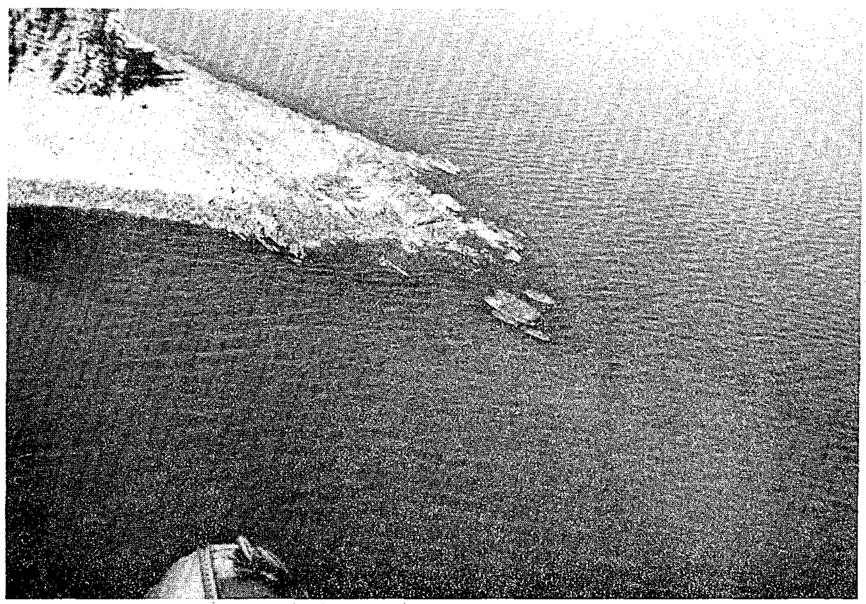


Fig. 47. Aerial view of Zaikol Bay sampling site. Taken in May 1974.

Dates and methods of sampling at Zaikof Bay are listed in Table 1. The distribution of some selected intertidal organisms is shown in Fig. 48 for fall, 1975. Appendix 1 contains a list of all species collected on the transects for all sampling visits. Rosenthal et al. (1977) include a description of the shallow sublittoral area adjacent to our intertidal site at Zaikof Bay.

Fucus formed the most conspicuous algal belt in the high intertidal zone at Zaikof Bay in 1974 and 1975 (see also Rosenthal et al. 1977). It occurred in greatest density from +9 ft (+2.7 m) to +5 ft (+1.5 m) but was found as low as +2 ft (+0.6 m). Dense concentrations of the mussel Mytilus edulis often occurred with the Fucus. With the Fucus/Mytilus assemblage were large numbers of inconspicuous organisms whose role in the intertidal system is not known. These include marine mites, pseudoscorpians, dipterans, oligochaetes and nematodes. Also present in quantity were the amphipod, Oligochinus lightii, and the isopod, Munna chromatocephala.

Below the +6 ft (+1.8 m) level the algal community included Palmaria palmata, Halosaccion glandiforme, Rhodomela/Odonthalia complex, Pterosiphonia bipinnata, Iridaea sp., and Cryptosiphonia woodii, listed in order of relative abundance. With this assemblage were many small molluscs, including Lacuna sp., Alvinia sp., Mitrella sp., Margaritas sp., Musculus sp., Hiatella arctica and Tonicella lineata and the crustaceans Pugettia gracilis, Pentidotea wosnesenskii, and Cancer oregonensis. The barnacle Balanus cariosus was distributed in densely concentrated patches from the +6 ft (+1.8 m) level to the +1.5 ft. (+0.4 m) level. At approximately the +3.5 ft. (+1.0 m) level Alaria marginata began to occur. This canopy species was common at the MLLW mark (0.0 m).

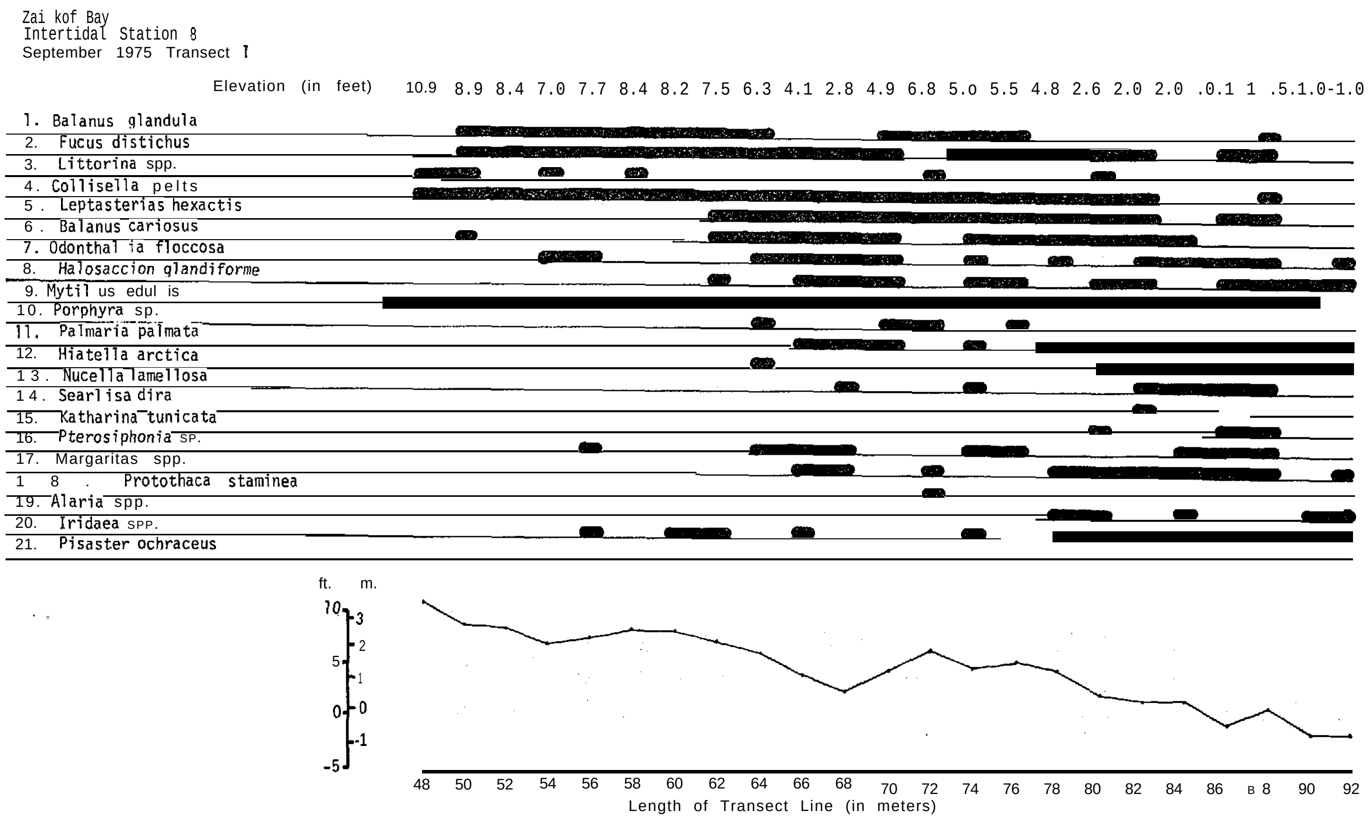


Fig. 48. Distribution of selected algae and invertebrates in 1/16 m^2 quadrats long transect 1 at Zaikof Bay in September 1975.

The sea star, *Pisaster ochraceus* was present in quantity although it appeared on only one transect line. During June 1976, intense *Pisaster* predation on *Mytilus* and *Balanus* spp. resulted in many patches of rock cleared of mussels and barnacles. These bare areas were then opened to colonization by species which suffer in competition for space with barnacles and mussels. A similar situation described by Paine (1966) resulted in an increase in species diversity by providing space, the major limiting resource in the rocky intertidal region (Paine 1966, 1971; Connell 1972; Dayton 1971).

MACLEOD HARBOR

Location and Physical Description

MacLeod Harbor (lat. 59° 53.4'N, long. 147° 47.7'W) is at the southwest end of Montague Island. Its broad mouth opens on Montague Strait (Fig. 1, and Sears and Zimmerman 1977, Plate EG-32). Our intertidal sampling site was on the north shore near the entrance of the bay, facing south, where it is partially exposed to seas from Montague Strait (Fig. 49).

The southwest end of Montague Island was raised about 9 m on March 27, 1964 by the Great Alaska Earthquake, which raised the entire intertidal zone of MacLeod Harbor well above the reach of highest tides, and moved substrate which had been subtidal into the intertidal region. Mass mortalities of algae and invertebrates resulted. An interdisciplinary post-earthquake study of Prince William Sound, led by G. Dallas Hanna (1971) included a visit to MacLeod Harbor on June 26-27, 1965. Johansen (1971) and Haven (1971) give accounts of post-earthquake algal and invertebrate distribution, respectively. At MacLeod Harbor in 1965, *Porphyra* spp. were the dominant colonizing algae, forming a heavy band from +8.0 ft (+2.4 m) to +3.9 ft (+1.2 m), the tidal range usually occupied by *Fucus distichus*, of which there were only a few isolated individuals

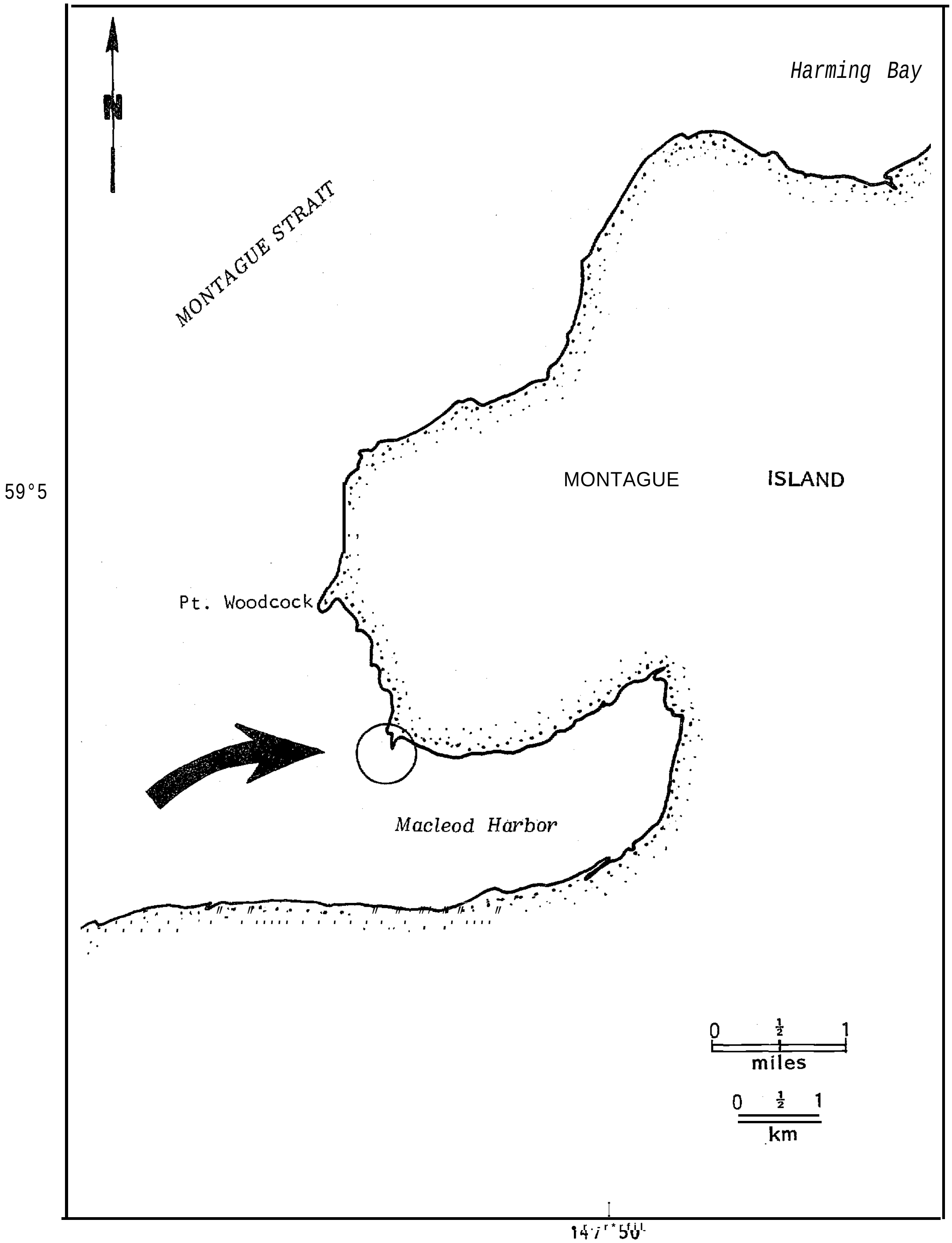


Figure 49. Mac Leod Harbor site.

(Johansen 1971). When Haven (1971) revisited the site in August 1968, and later when we visited it in 1974 and 1975 Fucus was the dominant alga of this zone.

Dates and methods of sampling are listed in Table 1. Appendix 1 lists all species collected at MacLeod Harbor for all sampling visits. Fig. 50 shows the distribution of some selected intertidal organisms at MacLeod Harbor in September 1975.

Our sampling site was largely bedrock, layers of which had buckled and heaved to create steep-sided "fingers" of rock which extend offshore from the high intertidal like fingers from a hand (Figs. 51 and 52). The upper part of these "fingers" was sampled with transect lines (Fig. 53) and the lower by arrow sampling (Fig. 51). The lower part of each transect traversed a low gradient, flat, bedrock shelf in the Alaria zone (which extends approximately from +5.0 ft (+1.5 m) to +1.0 ft (+0.3 m).

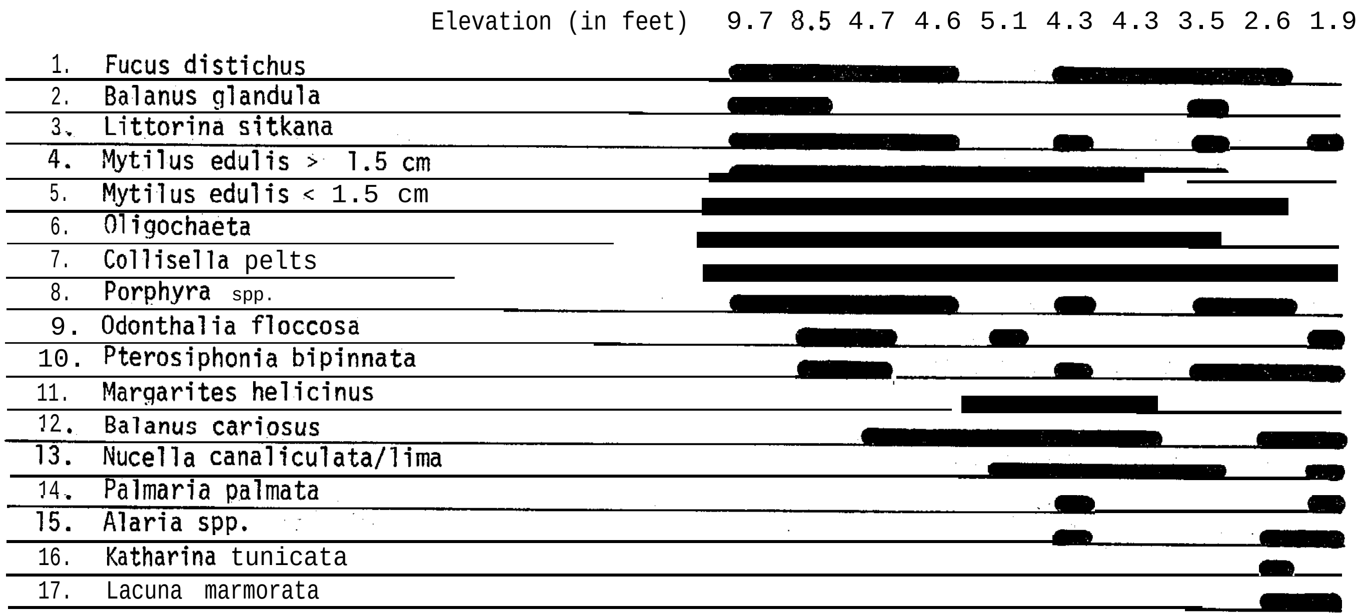
Dominant Organisms

Upper Zone

As at almost every rocky site sampled, the upper zone at MacLeod Harbor was occupied by Littorina sitkana, Balanus glandula, Fucus distichus and Mytilus edulis. Unlike other sites, on most transects collected at MacLeod Harbor, these species occurred in every zone we sampled down to +0.3 ft (0.1 m). Collisella pelta and oligochaetes were also distributed throughout the intertidal zone. An exception was Mytilus over 1.5 cm long which did not extend below +3.0 ft (+0.9 m) Pisaster ochraceus, which were observed in the low zone, may pass over small Mytilus edulis to select larger ones. Paine (1976) has found that there is a minimal size below which M. californianus are not attractive to large Pisaster.

In April 1975, Littorina sitkana were much less numerous in the collected quadrats than in September of 1974 and 1975 (average abundance in quadrats in

MacLeod Harbor
Intertidal Station 9
September 1975 Transect 2



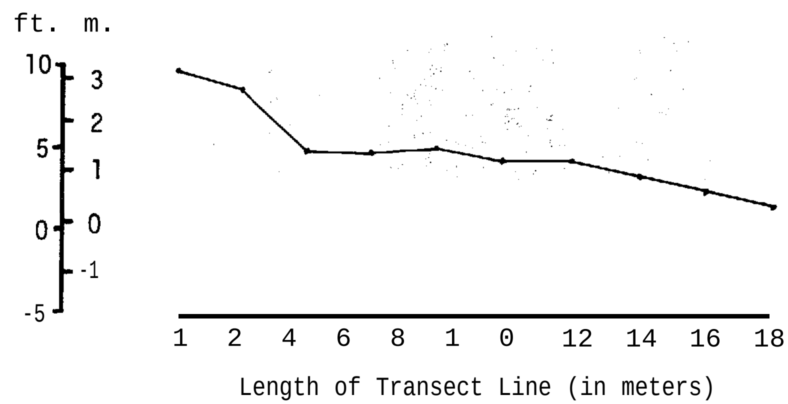


Fig. 50

Horizontal and vertical distribution of selected algae and invertebrates from 1/16 m2 quadrat collections along a transect line.

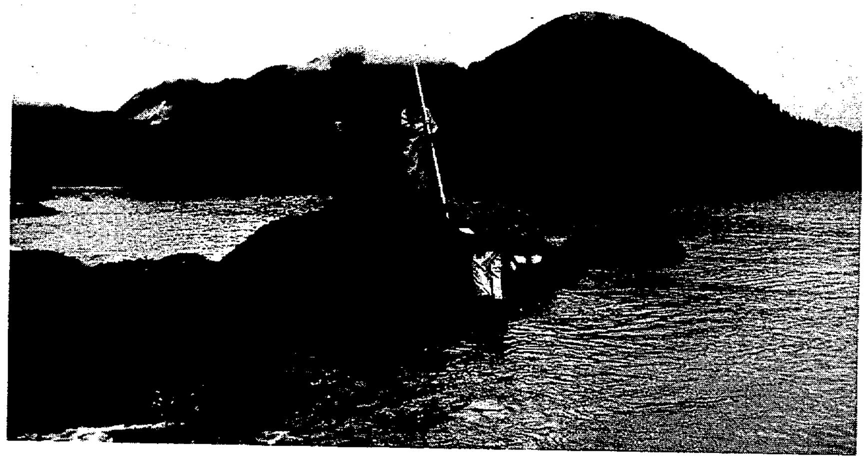


Fig. 51. Arrow sampling on a typical bedrock reef at MacLeod Harbor. Taken in September 1974.

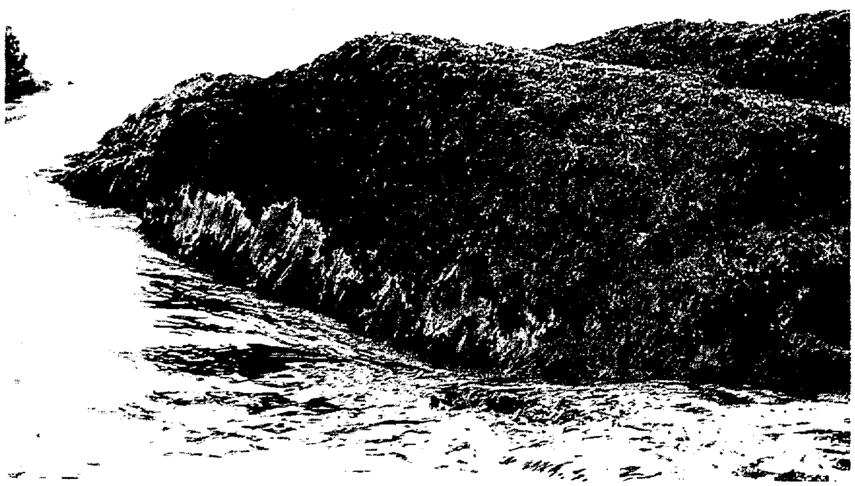


Fig .52. Low zone on reef showing heavy cover of mussels and algae. Taken in April 1975.

Fig. 53. Transect sampling in the upper zone at MacLeod Harbor. Taken in September 1975.

which they occurred was 7.9, April 1975; 104.4, September 1974; 71.6, September 1975). Near freezing weather during the April sampling period may have forced most L. sitkana to seek shelter in cracks, crevices and under rocks, These individuals would have been overlooked.

Middle and Low Zones

Mytilus, formed a heavy cover in the middle zone, particularly on the projecting reefs (Figs. 51 and 52). In the low zone the cover of Alaria spp. was relatively sparse. In September most of the Alaria plants still had their blades, although they were dissected to the mid-rib. In the extreme low zone, under water, we saw the starfish, Pisaster ochraceus and Pyncnopodia helianthoides, and the perennial red alga, Constantinea sp.

A prominent zone of the red alga, Palmaria palmata was absent at this site. All of our samples each had less than a gram of Palmaria. At other sites, weights of over 100 g of P. palmata per 1/16 m^2 quadrat were common.

LATOUCHE POINT, LATOUCHE ISLAND

Location and Physical Description

Latouche Point (lat. 59° 57.1'N, long, 148° 03.4'W) is on the southwestern tip of Latouche Island (Fig, 1 and 54 and Sears and Zimmerman 1977, Plate EG-33). “The point is exposed to westerly swells, and a great deal of drift accumulates along the beachline, especially during early fall and spring. Tidal currents are typically moderate to weak in the lee of the point. However, further offshore or in Latouche Passage where the water mass is not deflected by land, the tidal currents can exceed 2 nautical miles per hour”. (Rosenthal et al. 1977). Latouche Island was uplifted during the 1964 earthquake; the difference between the old barnacle line and the present barnacle line is about 3 m (Fig. 55). The sampling area is in the shape of a broad horseshoe bounded on the west by high

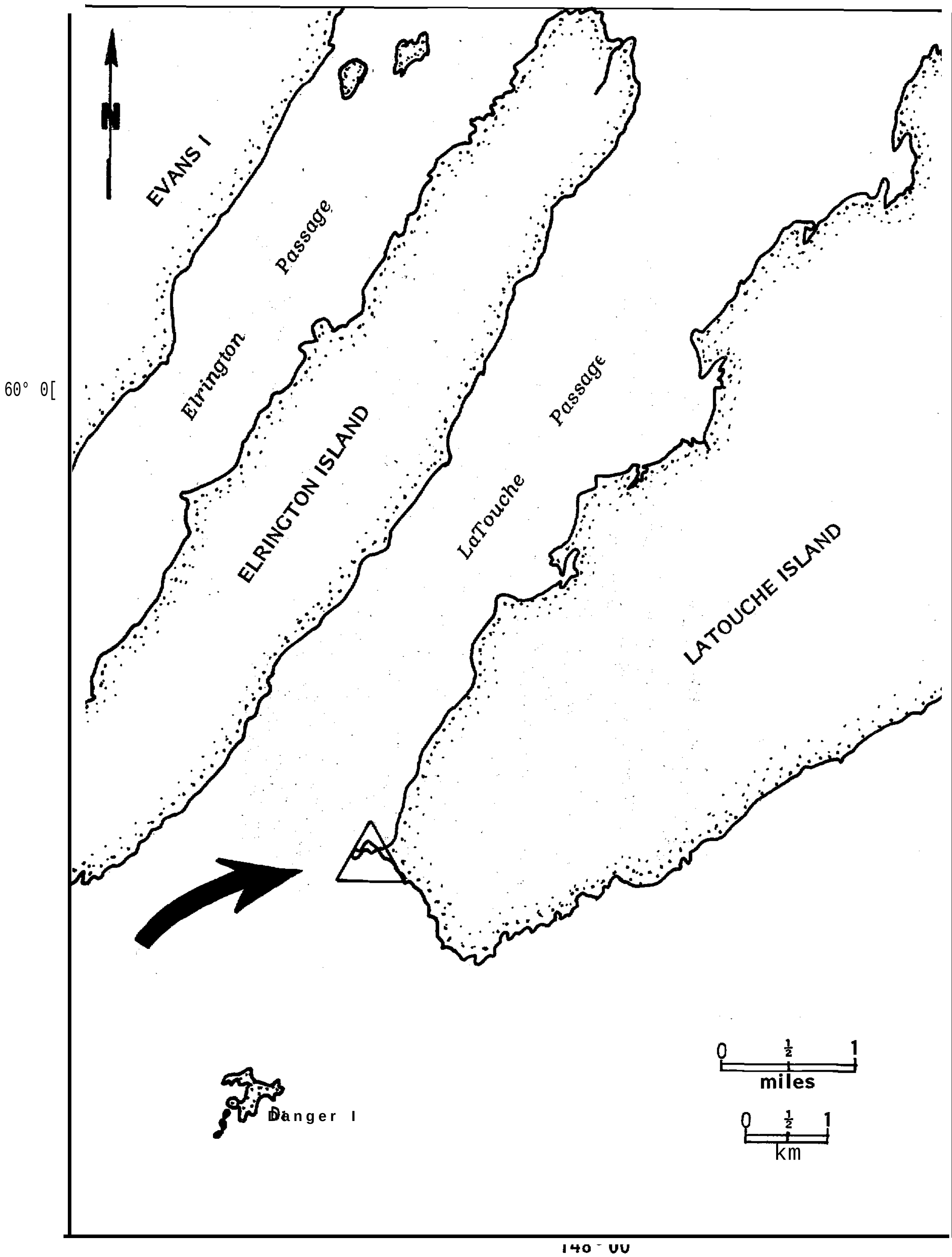


Figure 54. LaTouche Point site.

Fig. 55. Pre-earthquake (A) and present (B) barnacle lines at Latouche Pt. Uplift was approximately 3m.

Taken in June 1976,

spruce-covered cliffs, and on the East by hummocky bedrock (Fig. 56). The intertidal area is about 200 m broad and is gently sloping. The substratum is shale bedrock cut by many deep surge channels with sand and mud bottoms. There are several large, deep tidepools which we have never observed to go entirely dry.

Table 1 lists dates and sampling methods used at Latouche. Appendix 1 lists all species collected there for all sampling visits.

Dominant Organisms

In 1975 we established a transect along the west side of the beach in an area where large tidepools were common. Figs. 57 and 58 show the distribution of selected species along atransect sampled in April and September. We found that macrophytes and small invertebrates were abundant. In general the pools modified the effect of tidal elevation creating a mosaic pattern of distribution of macrophytes. Fucus distichus was most often observed in the high zone above the tidepools or on rock tops near tide pools. Dense patches of the surf grass, Phyllospadix sp. were associated with the borders or on the sloping sides of large tidepools (Fig. 59). Sand had collected among the rhizomes of this plant and many polychaete and oligochaete worms, clams, isopods, and amphipods were collected with the Phyllospadix plants. Many species of red algae, especially Ptilota filicina, and kelps were found at a higher tidal elevation than one would expect them to occur, probably because of the effect of surge channels and tidepools which reduce dessication at upper levels.

Most of the invertebrates in our collection were small herbivores, (Littorina sitkana, Siphonaria thersites, and Collisella pelts), filter feeders (bivalve mollusks including Musculus discors and Turtonia occidentals), or

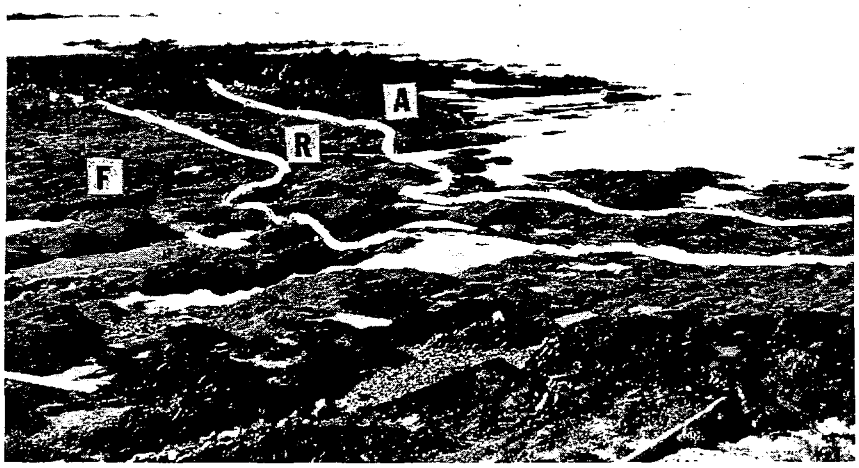


Fig. 56. The two undulating white lines indicate the boundaries of the main algal zones during the **ERIM study of 1976. F, *Fucus* zone; A, red algae and *Alaria*; R, diverse cover of red algae {see text) . Taken in June 1976.**

Intertidal study site at Latouche Point.

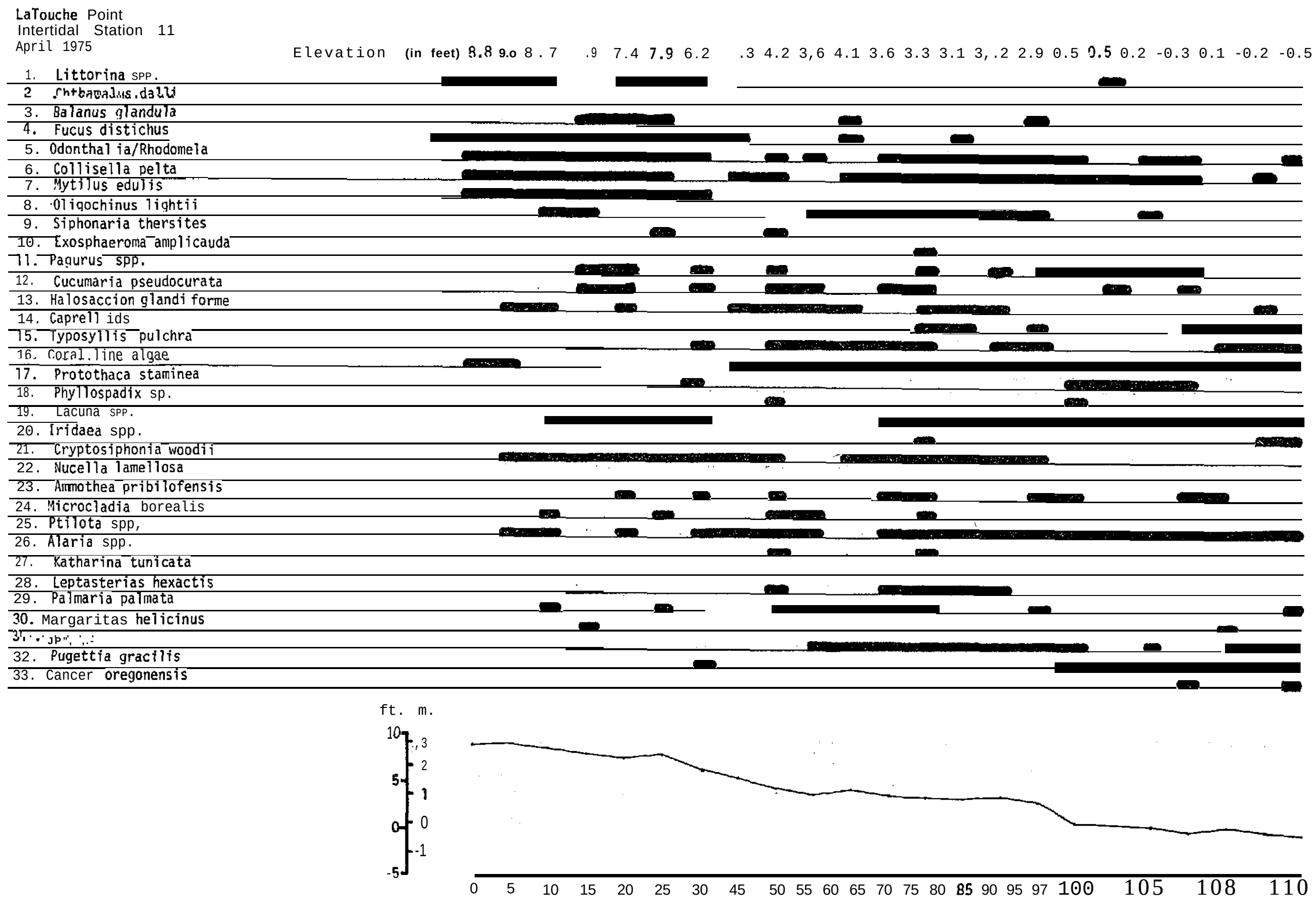


Fig. 57. Distribution of selected plants and invertebrates in 1/16 m^2 quadrats at station 11 at Latouche Point in April 1975.

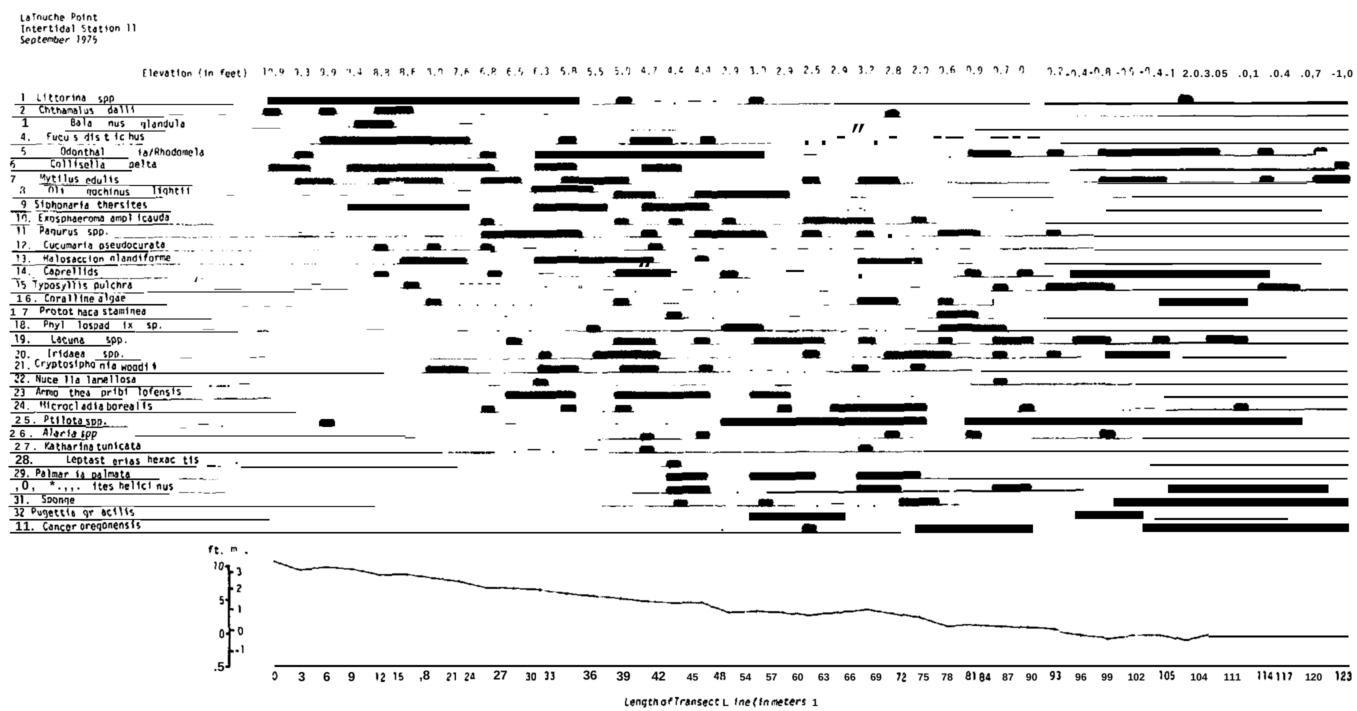


Fig. 58. Distribution of selected plants and invertebrates in 1/16 m^2 quadrats at station 11 at Latouche Point in September 1975.

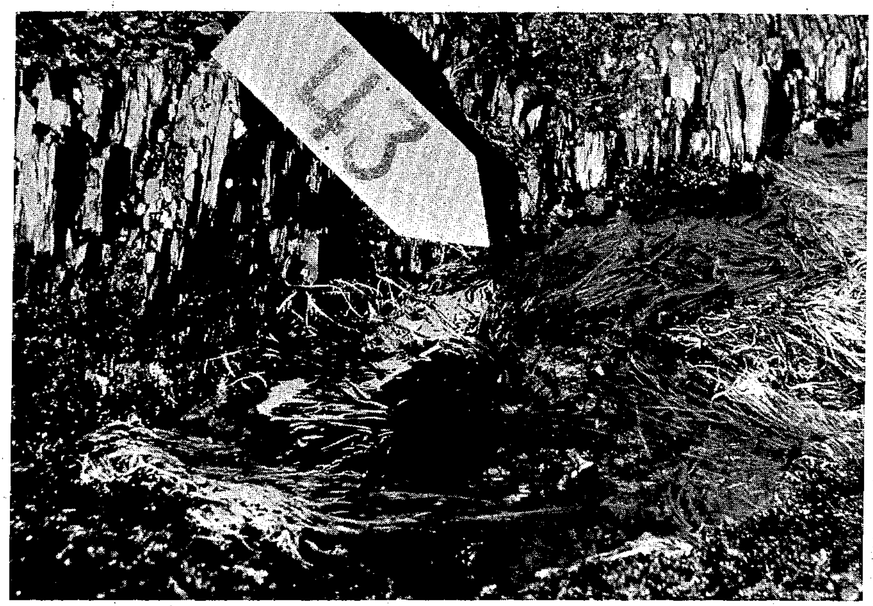


Fig. 59. *Phyllospadix* growing on the sides of a deep tidepool. Taken in April 1975.

detrital feeders (amphipods, Cucumaria pseudocurata, and Pagurus hirsuitiusculus), often associated with macrophytes. Predators were rare. We found only five Nucella (Nucella sp. and N. lamellosa) in our quadrat collections for April and September. We collected 12 Leptasterias hexactis in April and only four in September. Juvenile sea stars, too small to identify[1/] were abundant in September. We collected 122 juvenile sea stars in seven quadrats ($\bar{x}$=17.4/quadrat) at elevations ranging from +2.0 to +4.7 ft (+0.6 to +1.4 m). Mussels and barnacles were uncommon along the transect. Most of the mussels collected were less than <1.5 cm. Barnacles (Balanus glandula, B. cariosus, and Chthamalus dalli) were found on occasional boulders which may be tumbled during storms and on shale bedrock which is fr· able (Fig, 60). We observed denser aggregations of mussels and barnacles on stable bedrock outcrops east and west of our sampling area.

In 1976 we made a qualitative survey on the same beach, as part of a cooperative study with the Environmental Research Institute of Michigan (ERIM), to determine if multi-spectral scanning by aircraft could be used to determine macrophyte distribution and abundance in the littoral zone. A 200-meter transect line was run along the east side of the beach and estimates of percent cover were made for each meter along the transect. The east side of the beach had many surge channels but had fewer tidepools than the west side previously investigated. Fucus formed a broad band, about 65 mwide, in the high zone (Fig. 56). Below this band a narrow zone of several species of red algae was found; Alaria sp. formed the canopy in the lower end of this zone (Figs, 56 and 61). The lowest zone was

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1/ From data sheets of the sorting center of the Institute of Marine Sciences, University of Alaska, Fairbanks.

Fig .60. Barnacles growing on shale bedrock and on boulders. Taken in September 1975.

Fig. 61. Lower and mid-intertidal zone with cover of Rhodophycean turf species, Alaria canopy, Laminaria in the tide pool and Phyllospadix at the pool border. Taken in September 1975.

formed of flat peninsulas separated by surge channels. These peninsulas had a dense cover of Ptilota filicina, Odonthalia floccosa, Iridaea cornicopiae, and Iridaea heterocarpa. The surge channels were filled with the kelps Laminaria sp., Cymathere triplicate, and Agarum cribrosum, as well as the subtidal red alga Constantinea rosa-marina.

Rosenthal et al. (1977) have studied sublittoral plant and animal assemblages at Latouche Point.

SQUIRREL BAY

Location and Physical Description

Squirrel Bay is a semicircular bay on the southwestern tip of Evans Island that opens on the southern entrance of Prince of Wales Passage into Prince William Sound (Fig. 1 and Plate EG-34, Sears and Zimmerman 1977). Because of its wide mouth much of the bay is exposed to oceanic swell from Blying Sound to the southwest, but our sampling site on the south shore near the entrance (lat. 59° 59′ 54″N, long. 148° 08'58"W) was relatively protected from these swells (Fig. 62).

The site had an especially "hummocky" topography created by boulders in a wide range of sizes. A moderate cover of algae on the boulders made the beach difficult to traverse. We visited Squirrel Bay in September 1974 only, and our collections and observations are limited.

In the collected quadrats Fucus biomass was highest at and above +6.7 ft (+2.0 m) (n=6, mean wet wt. = 265.4 gm, SD=89.5 gin). Within this tidal range 53% (by wet wt.) of the Fucus plants showed signs of fertility. From +6.1 ft (+1.9 m) to +2.7 ft (+0.8 m) Fucus biomass was much less (n=8, mean wet wt. = 23.9 gm, SD=27.7 gm) and fertile plants occurred in only 25% of the quadrats (9% by weight were fertile).

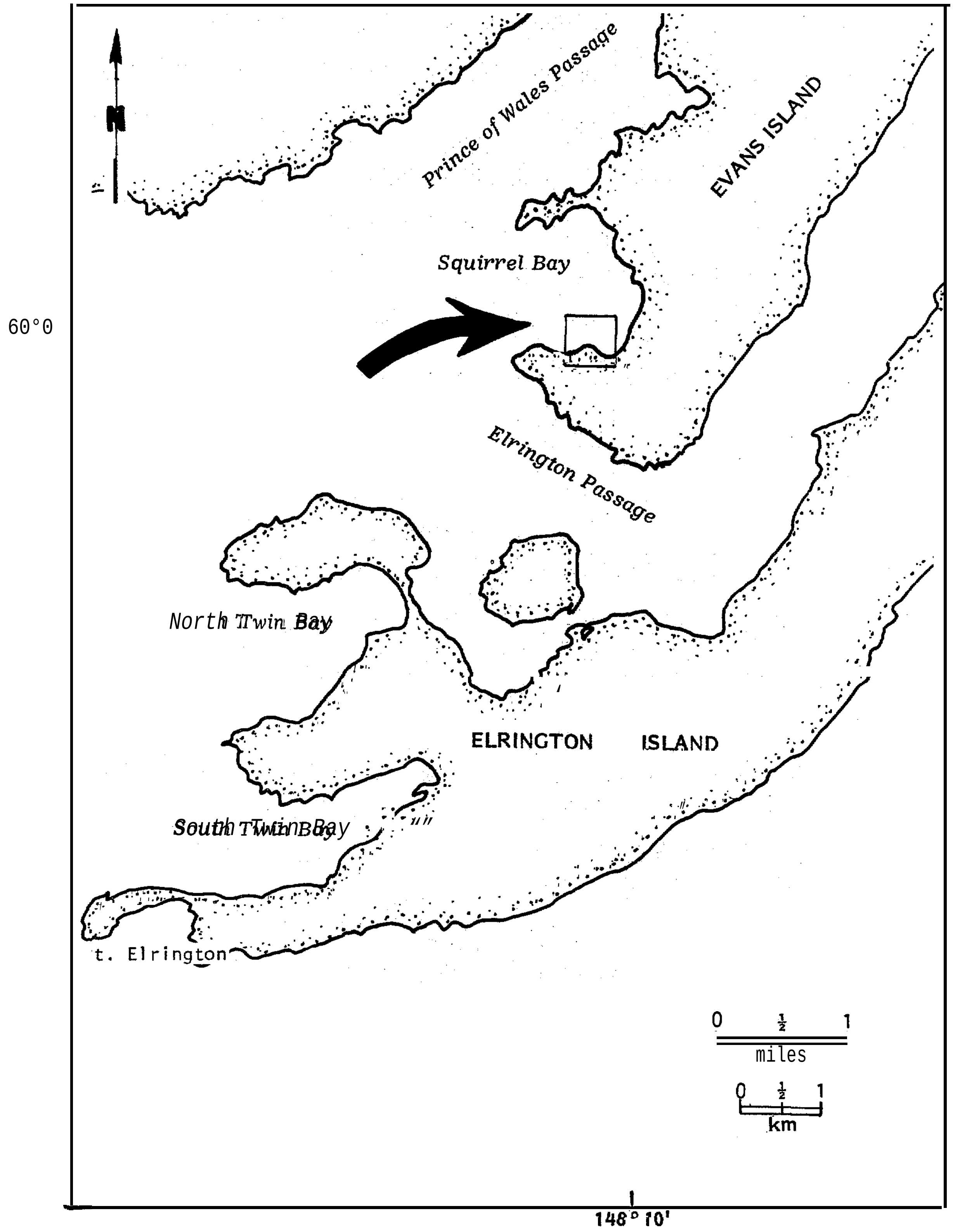


Figure 62 . Squirrel Bay "site.

The distribution of biota at the site was patchy. This may have been partly related to the varied slope and aspect imparted by boulders of a variety of sizes, providing a wide variety of habitats, which in the lower zone particularly were populated by a rich fauna. Algae in the area were limited to the tops and sides of boulders presumably either by herbivores or by the availability of light, the lower and undersides of the boulders provided space and shelter for many animals. Because of the limitations of the transect sampling method, many of these habitats were not sampled. As an example of the diversity of organisms among the boulders in the low zone we made field identifications of the following organisms on one boulder (about 60 cm in diameter) not on the transect: encrusting bryozoans, sponges, four species of anemone (*Tealia crassicornis*, *Anthopleura artemesia*, *Metridium senile*, and one unidentified species), a nemertean, the polychaete, *Spirorbis* sp., three species of echinoderm (a brittle star, *Leptasterias* sp., and *Pisaster ochraceus*), snails (*Margaritas beringensis* and *Nucella lamellosa*), the hermit crab, *Pagurus* h. *hirsutiusculus*, a small chiton, *Mopalia*, and tunicates. Appendix 1 lists all species collected in samples from Squirrel Bay.

ANCHOR COVE

Location and Physical Description

Anchor Cove is a 3/4 mile wide recess in the eastern shore of Day Harbor, a larger embayment opening into Blying Sound in the Gulf of Alaska (Fig. 1). The intertidal survey site is located on the unnamed point (lat. 59° 59'42"N, long. 149° 06'06"W) that forms the southern boundary of Anchor Cove (Fig. 63). The point is a short bedrock reefof moderate slope. It is bordered on either side by near-vertical bedrock substratum (Sears and Zimmerman 1977, Plate EG-36). Dates and methods of sampling are listed in Table 1.

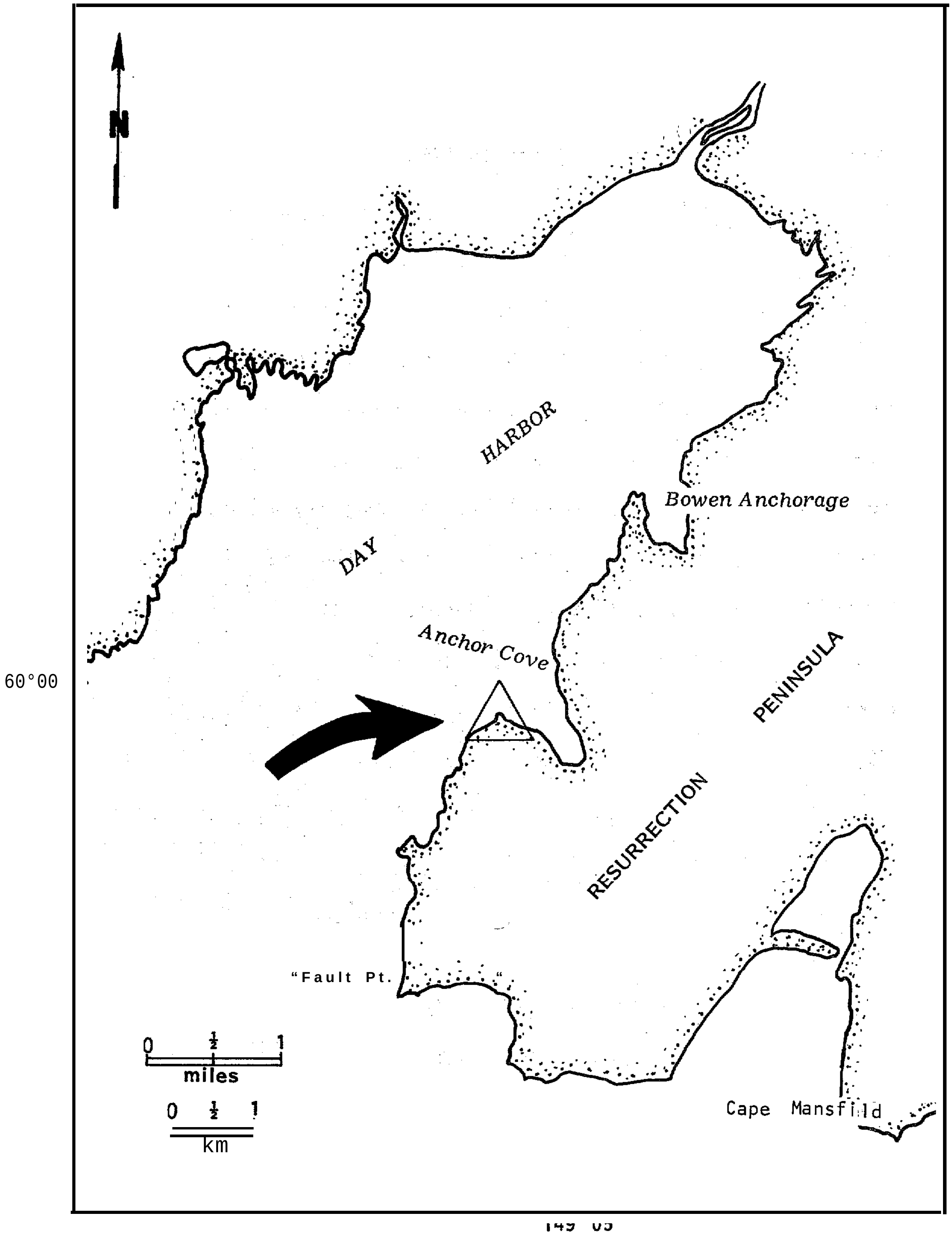


Figure 63 . Anchor Cove site.

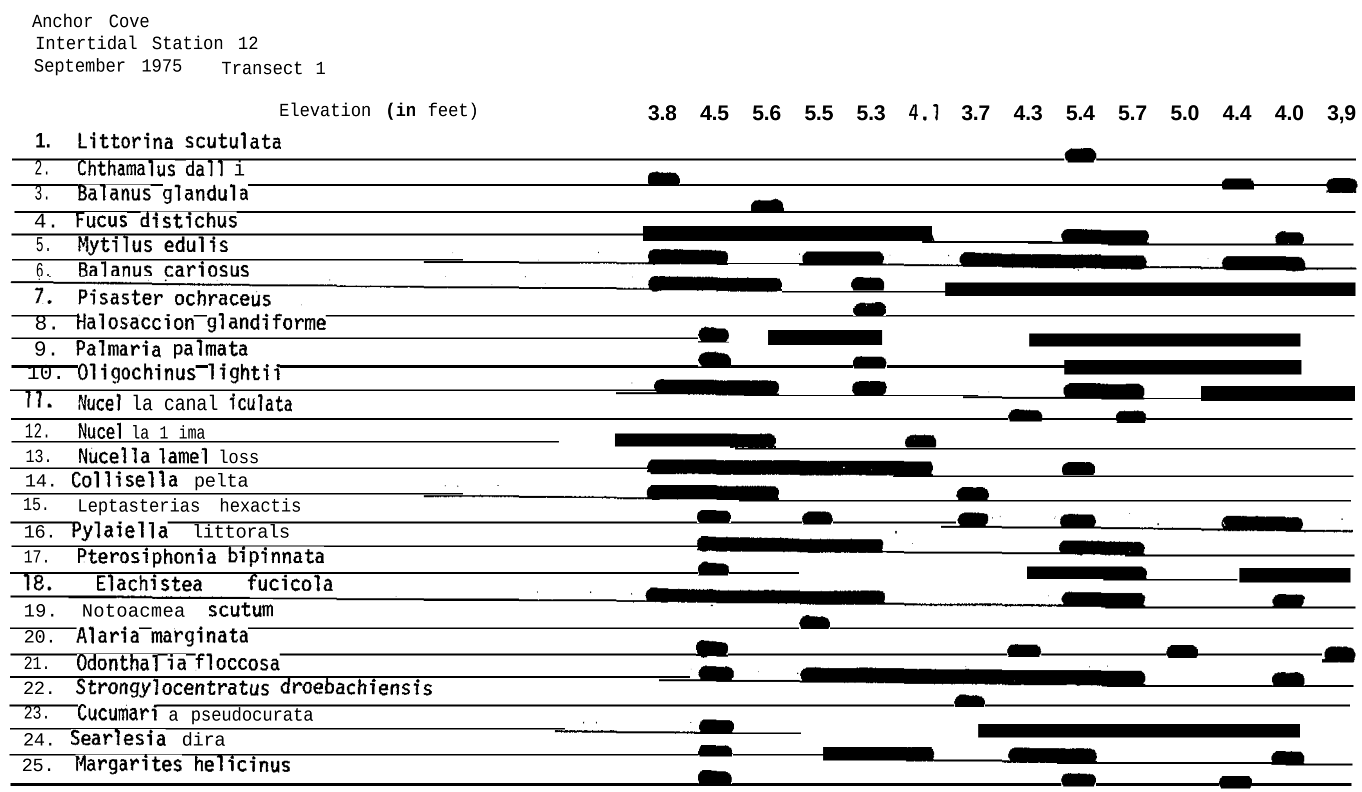
The distributions of some selected species collected along one transect are shown in Fig. 64 for September 1975. Appendix 1 contains a list of all species collected on the transects at Anchor Cove.

There was a striking difference in the pattern of abundance of mid-intertidal biota between the spring and fall visits in 1975. This can be seen in Figs. 65, 66, 67, and 68. In May, a large area of the reef was covered with a dense growth of the mussel, Mytilus edulis, over-laying live Balanus cariosus. By September the total area of mussel coverage had been reduced by an estimated 80% to a few isolated patches on small hummocks and was being replaced by algae (Halosaccion glandiforme and Ulva sp). A similar pattern of Mytilus-abundance to that in September 1975 was noted ayear earlier at the same study area(Figs. 69 and 70).

The reduction in size of the mussel bed was probably a result of predation by the gastropod Nucella lamellosa and N. lima and the sea star Pisaster ochraceus. The few remaining mussel patches were surrounded by actively preying Nucella and drilled, empty mussel valves (Figs. 66, 67, 68, and 70). Nucella spp. usually feed on barnacles (Balanus spp. and Chthamalus spp. (Moore 1938, Connell 1970, Dayton 1971, Bertness 1977)). However, Menge (1976) correlated an increase in the proportion of mussels, M. edulis, in the diet of Nucella lapillus with an increase in the abundance of mussels and that Nucella severely reduces populations of mussels in protected situations.

Predation by Pisaster was not observed as it eats primarily while submerged and seeks refuge at low tide (Mauzey 1966). However, Landenberger, (1968) Mauzey et al. (1968) and others have shown that Pisaster has a definite preference for mussels. Paine (1966) has shown experimentally that Pisaster is of primary importance in determining the composition of rocky intertidal biota.

It is not likely that the loss of mussels was the result of other factors such as storm damage or predation by mink, crows or sea birds. Storm damage would



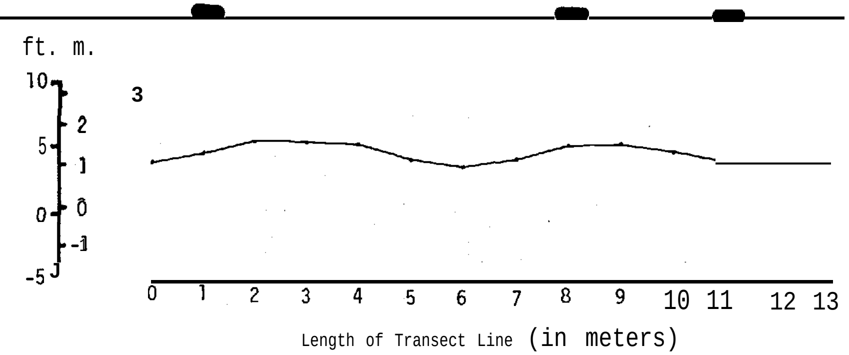
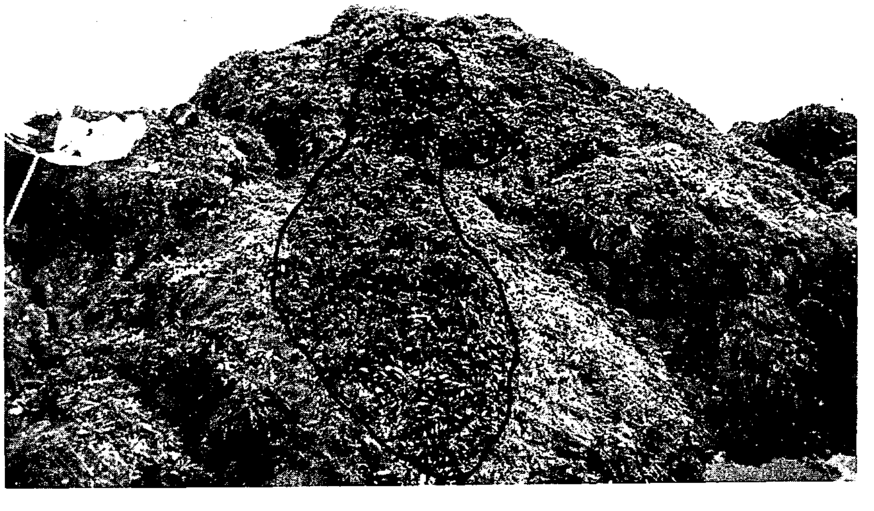


Fig. 64.

Horizontal and vertical distribution "of selected algae and invertebrates from 1/16m² quadrat collections along a transect line.

Fig .65. Anchor Cove, May 1975. Much of the area around the two biologists is covered by M. edulus.



Fig, **66. Anchor Cove, September 1975. Showing extent of Mytilus coverage (within black line) . Location is immediately to the left (viewer right) of the people in Fig.65).**

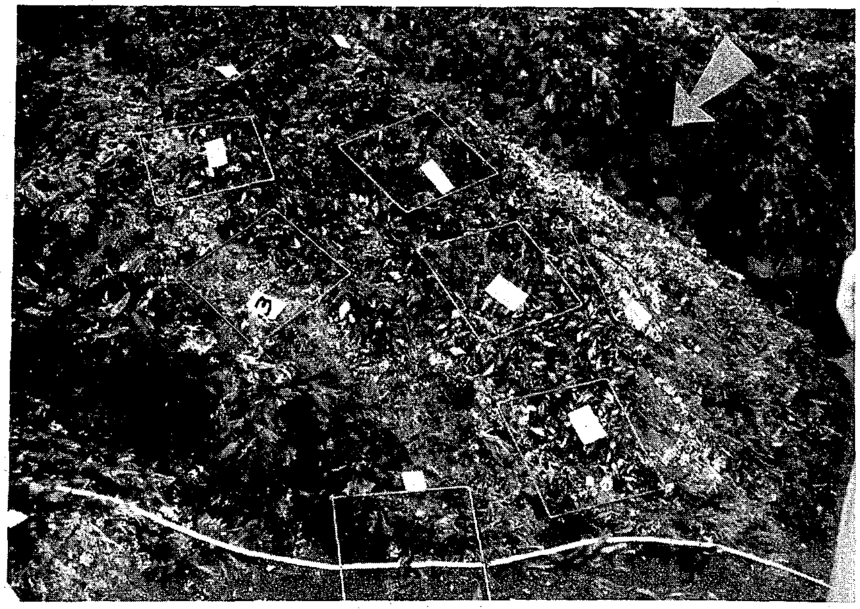


Fig. 67, Close-up of study area at Anchor Cove showing Nucella (mostly N. lamellosa) preying on M. edulis. Note also the concentration of Pisaster ochraceus (arrow). Taken on 3 September 1975.

Fig. 68. Close-up of one quadrat in Fig. 67 showing shells of Mytilus (arrows) which have been drilled by Nucella. Taken on 3 September 1975 by C. Mattson.

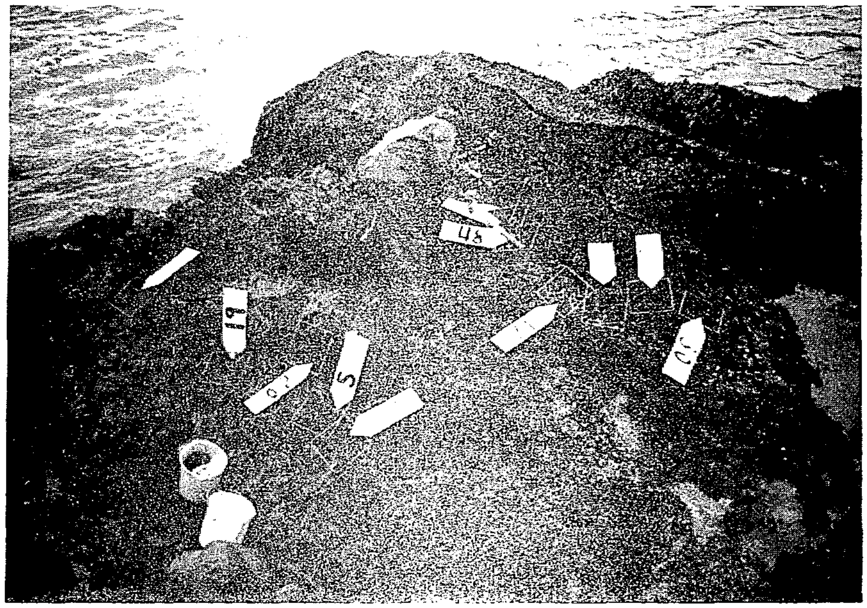


Fig.69. Study area at Anchor Cove. Taken on 15 September 1974 by $?. Myren. Note wave of Nucella to the right of line marking edge of Mytilus patch.

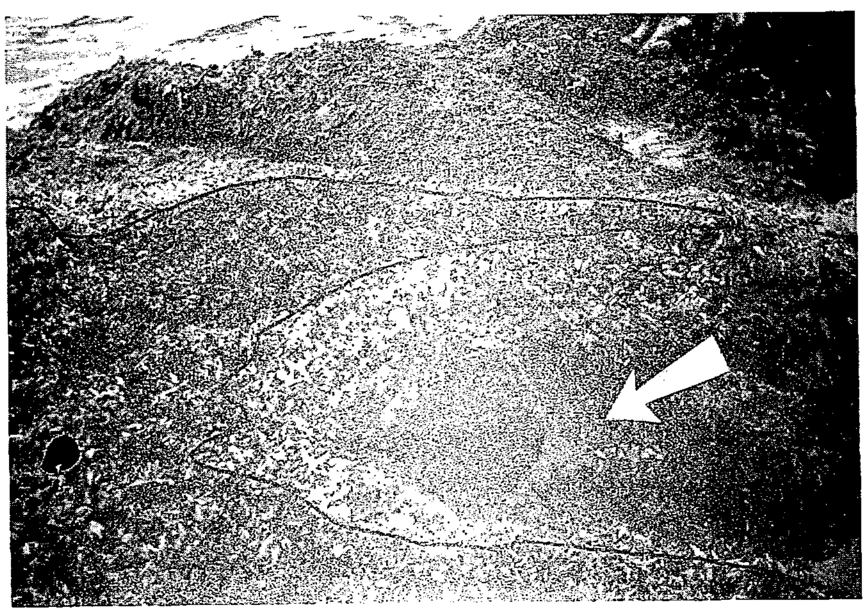


Fig.70. close-up of a wave of Nucella **from Fig.69(line** denotes margin of Mytilus patch). Note several Pisaster **(arrow) . Taken on 15 September 1974 by R.Myren.**

have occurred primarily on the seaward side. This was not the case as predation was not oriented with respect to wave impact. Predation by mink, crows or sea birds would have been from above, or in a descending direction, however, since the remaining mussels were confined to the tops of hummocks, predation must have occurred from below, or in an ascending direction (Figs. 66 and 69).

That the mussel bed was so extensive and relatively predator-free in the spring can be explained by the habits of the predators. Mauzey (1966) reports a seasonal feeding periodicity in Pisaster in which the percentage of feeding individuals observed varied from 80% in the summer to 0% in the winter. On San Juan Island, Washington Nucella lamellosa moves from lower intertidal levels in spring to higher levels in fall as it depletes its primary food source (barnacles); most Nucella stop feeding from November through February (Connell 1970).

GORE POINT

Location and Physical Description

Our intertidal station (lat. 59° 13'20"N, long. 151° 01'00"W) was located approximately 2 miles northwest of Gore Point, in the entrance to Port Dick (Figs. 1 and 71). The beach consists of moderately sloped bedrock overlain by a few boulders (Fig. 72; Sears and Zimmerman 1977, Plate EG-46).

Table 1 shows the dates we visited Gore Point and our sampling methods. Figs. 73 and 74 illustrate the distributions of some selected species collected along a transect in May 1975 and August 1975. Appendix 1 lists all species collected on the transects for all sampling periods.

The upper intertidal zone (+11 to +13 ft (+3.3 to +3.9 m) was covered by a heavy (often 100% coverage) growth of the red alga, Porphyra sp. Also present were insect larvae, Balanus glandula, Littorina sitkana and Collisella digitalis, none of which were unusually abundant.

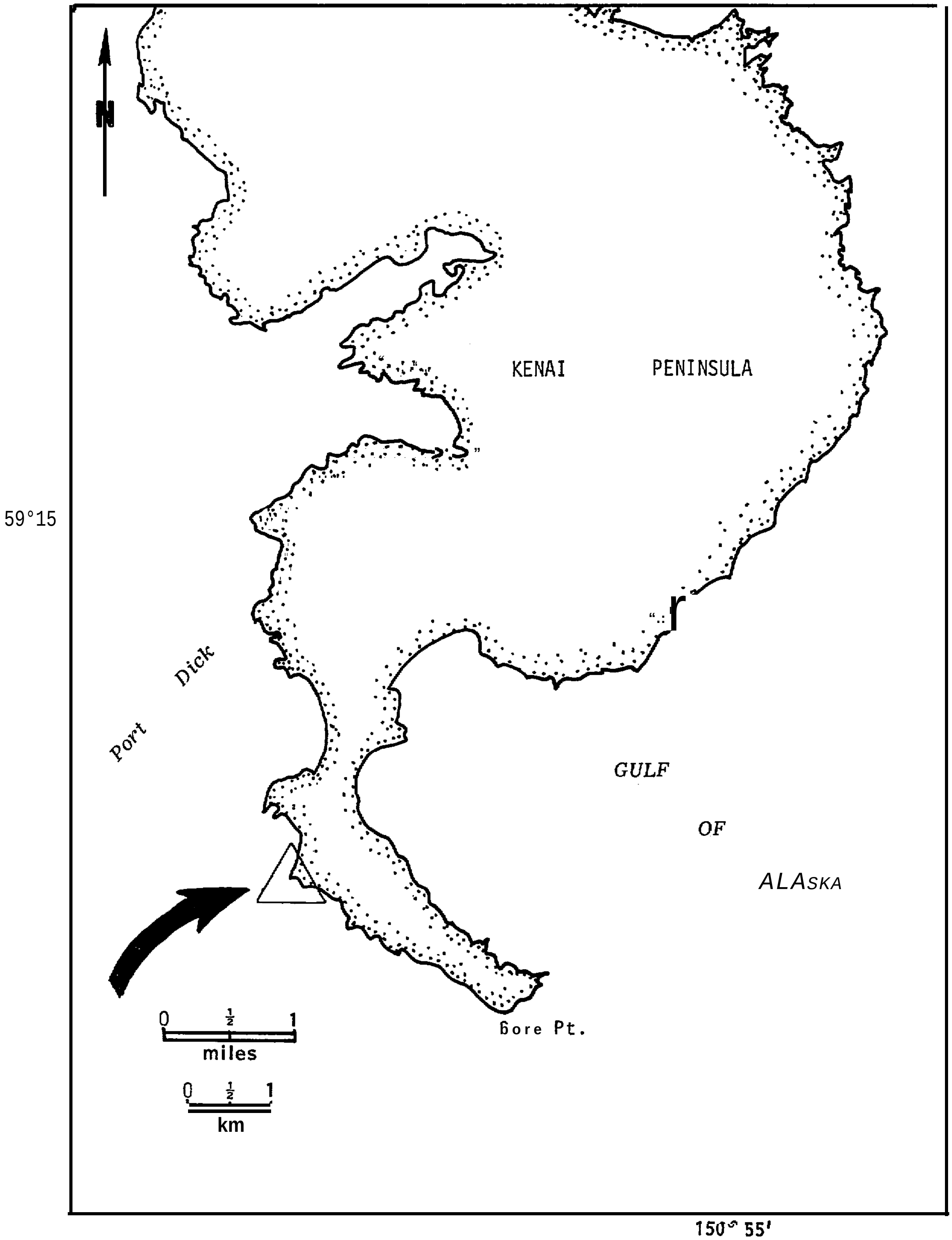


Figure 71 Gore Point site

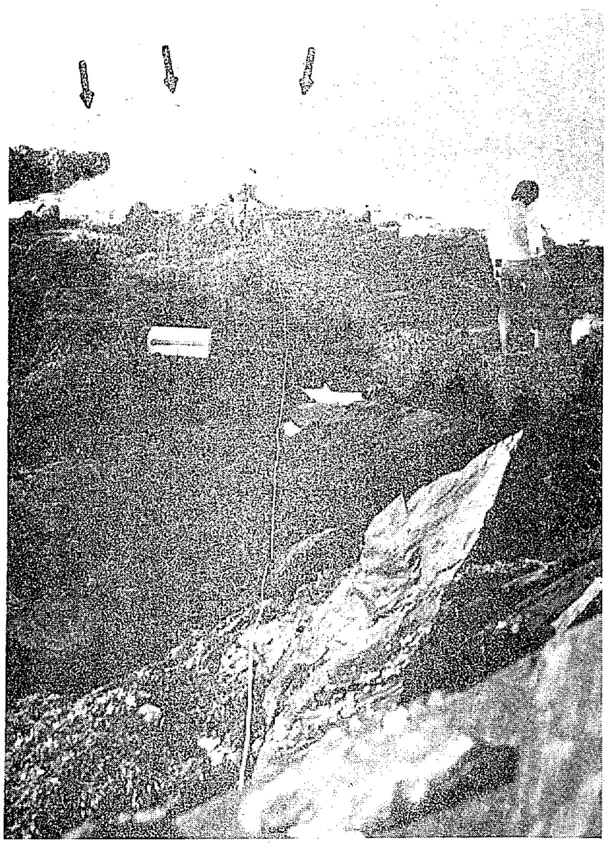


Fig. 72. Transect line at Gore Pt. in August 1975. The floating kelp Nereocystis leutkeana is visible immediately offshore (arrows) .

Gore Point
Intertidal Station 13
May 1975

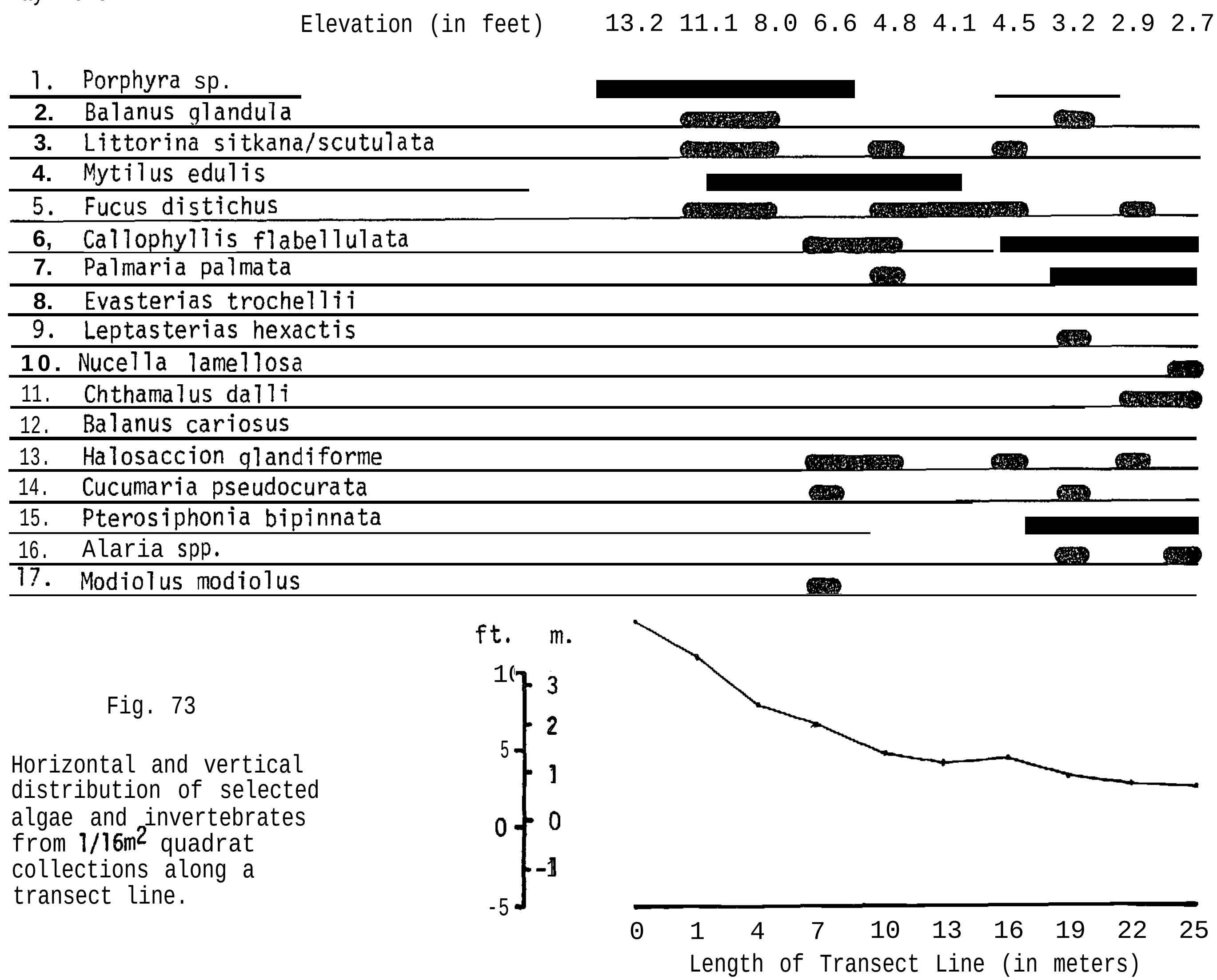


Fig. 73

Horizontal and vertical distribution of selected algae and invertebrates from 1/16m² quadrat collections along a transect line.

Gore Point
Intertidal Station 13
August 1975

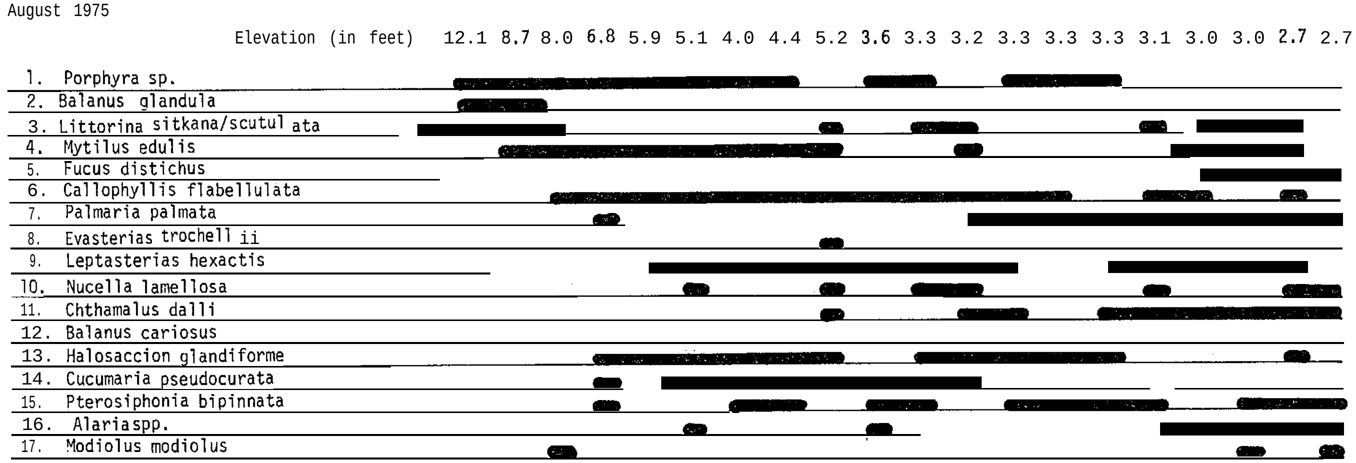
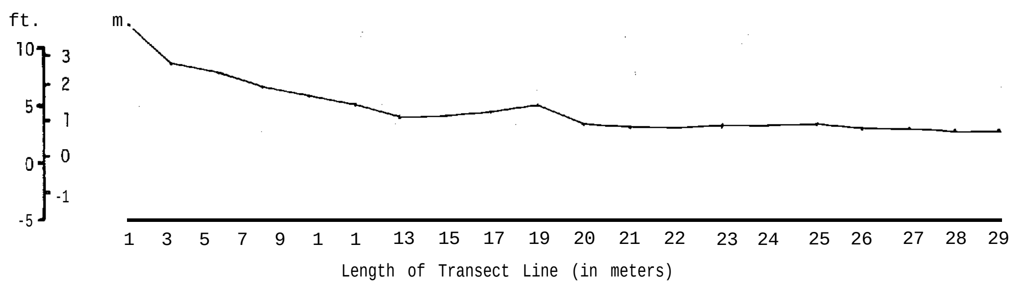


Fig. 74

Horizontal and vertical distribution of selected algae and invertebrates from 1/16m2 quadrat collections along a transect line.



Below this zone (from +5 to + 11 ft (+1.5 to +3.3 m)), Mytilus edulis and the assemblage of inconspicuous microfauna (oligochaetes, polychaetes, flatworms amphipods, isopods and small molluscs) among its byssal threads formed a discontinuous but dense mat over the substratum. Although Evasterias troschelli, Leptasterias hexactis and Nucella lamellosa were present, evidence of heavy predation was not observed.

Below the upper barnacle-mussel zone, Palmaria palmata and Callophyllis flabellulata covered extensive areas of bedrock (+3 to +8 ft (+0.9 to +2.4 m). Halosaccion glandiforme, Porphyra sp., Pylliella littorals and Monostroma fuscum often co-occurred with Palmaria and Callophylis but were patchy in distribution. The barnacle Balanus cariosus, which commonly is a dominant in this zone (Dayton 1971) was conspicuously low in abundance. However, the small barnacle Chthamalus dalli was distributed extensively in this zone. Dayton (1971) has shown that competition for primary space (the main limiting resource in the intertidal zone) results in clear dominance heirarchies in which B. cariosus is dominant over both B. glandula and C. dalli, and B. glandula is domiant over C. dalli. The upper limit of C. dalli is higher than those of Balanus spp. and C. dalli is normally excluded only at lower levels where Balanus spp. are abundant. The abundance of C. dalli may have resulted from the scarcity of both species of Balanus, but our data are inadequate for examining the question.

Alaria sp. formed a canopy below +3.5 ft (+1.0 m). Cryptosiphonia woodii, Pterosiphonia bipinnata, Ptilota sp., Callophylis and Palmaria were abundant, Also numerous were Searlesia dira, Katharina tunicata, Modiolus modiolus Cucumaria pseudocurata and Musculus sp. Close offshore was a bed of the floating kelp Nereocystis leutkeana (Fig. 72).

Species Diversity

We consider species diversity in the broad sense including (1) species richness as approximated by average species counts in 1/16 m^2 quadrats and species-area (sample size) curves, and (2) the distribution of individuals among species. A number of indices combining these two aspects of species diversity have been offered in the literature (see Peet 1974 for a recent review). Diversity indices are of dubious value for determining the biological mechanisms that are basic to community organization (Hurlbert 1971, Goodman 1975) and are insensitive to changes in the character of the distribution functions of species abundance in those situations when the functions should be most informative (May 1975). We do not use diversity indices here.

Average species counts

Species counts in samples from quadrats scraped in September 1975 are shown in Table 4, Nearly all samples at most rocky intertidal sites were taken between mean high water (MHW) and mean low water (MLW) except at Cape St. Elias where all rocky intertidal samples were taken below MLW in September 1975. The region between MHW and MLW at all sites was divided into upper and lower intertidal zones following Rigg and Miller's (1949) scheme for the outer coast of Washington (Table 4).

Three of our rocky intertidal sites are excluded from Table 4, Port Etches and Gore Point because they were not sampled in September, and Cape St. Elias because all samples were collected from below MLW, and therefore were not comparable to the other sites. Squirrel Bay was not sampled in September 1975; data from September 1974 are shown in Table 4. Counts of the following taxa are excluded because organisms from them were usually not identified more specifically than to phylum or class: Porifera, Cnidaria, Platyhelminthes, Nemertea (except Emplectonema gracilis), Oligochaeta, Copepoda, Insects (except

Table 4. Average species counts of plants and invertebrates in quadrats (1/16 m^2) at rocky intertidal areas in the Eastern Gulf of Alaska.

Site	Upper intertidal area: Number of quadrats	Upper intertidal area: Species count		Lower intertidal area: Number of quadrats	Lower intertidal area: species count	
	N	$\bar{x}$	SD	N	$\bar{x}$	SD
Ocean Cape	5	10.4	2.5	6	13.7	5
Cape Yakataga	18	14.4	3.4	15	15	4.1
Katalla Bay	9	8.8	3.8	20	13.4	4.4
Zaikof Bay	16	15	5.6	16	25.9	6.7
Macleod Harbor	13	14.2	4.5	17	19.5	6.4
Squirrel Bay	9	8.2	3.2	8	14.9	7.3
Latouche Point	9	18.9	7.6	19	32.7	8.3
Anchor Cove	8	19.4	4,2	26	25.2	6.9

Anurida maritima), Acarina, Sipuncula, Bryozoa and Ascidiacea.

Highest species counts both in the upper and lower intertidal areas were recorded at Anchor Cove, Latouche Point and Zaikof Bay (Table 4). These three sites are relatively exposed to open ocean swell. Increased wave exposure raises the "effective wetting level" (Lewis 1964) of the sea and consequently the upper limits of marine organisms. Therefore, one might expect more species to occur at higher levels in the intertidal region on exposed shores. Nevertheless, relatively low species counts were recorded for the exposed sites, Ocean Cape and Cape Yakataga. There, frequent disturbance by wave-induced boulder movement and ice and sand scouring may offset the "diversifying" effect of increased exposure, but the nature of our studies did not allow an adequate examination of other factors which could affect species richness such as competition and predation. Intense predation on populations of M. edulis by P. ochraceus was noted at Anchor Cove and Zaikof Bay (but not Latouche Point), whereas large predatory starfish appeared to be uncommon at Ocean Cape and Cape Yakataga (see descriptions of sites earlier in this section). Predation by Pisaster has an important diversifying effect on an intertidal community (Paine 1966; see earlier site descriptions of Anchor Cove and Zaikof Bay). Therefore, the presence or absence of large predatory starfish may influence species richness at our sites to a great extent.

Species area curves

To study species richness and species abundance relations more closely we examined associations of organisms found at about mean tide level (MTL; +1.5- +2 m in the-eastern Gulf of Alaska depending on the locality) because on the average the sea-surface passes this level more frequently than any other intertidal level. This level would therefore be expected to be contaminated more frequently than any other by oil floating on the sea after an oil spill (although wave action would probably cause the oil to be mixed to levels well below the sea-surface). Specifically we considered data from plots dominated either by Mytilus edulis or Fucus spp.. These two species overlap nearly completely in vertical range (+1 m to +3.3 m) at our study sites, although Fucus spp. was usually found both above and below Mytilus.

Fucus and Mytilus were considered to dominate when their wet weights exceeded 110 gm and 600 gm respectively. Comparisons of data on wet weight and percent cover from Anchor Cove indicated that percent cover of Mytilus edulis and Fucus spp. exceeded 80% when wet weights exceeded 110 gm and 600 gm. Using these criteria an adequate sample size ($n \geq 5$) was available from three sites, Ocean Cape, Zaikof Bay, and Anchor Cove. However, only at Zaikof Bay did the sample size approach that required to include all species in the assemblage (the taxa excluded are the same as those excluded from the mean species counts) associated with each dominant (Fig. 75). There was not an adequate number of Fucus dominated plots collected at Ocean Cape. In order to obtain an adequate sample size for Anchor Cove and Ocean Cape samples from September 1974 and 1975 were lumped,

The slopes and heights of the species-area curves for mussel-dominated plots at Anchor Cove and Zaikof Bay were greater than those for Ocean Cape (Fig, 75). The Smirnov test (Conover 1971) of the empirical species-area distributions showed that the tendency for the cumulative species counts to exceed those of Ocean Cape was significant for Zaikof Bay but not Anchor Cove (Table 5). As noted above, the species-area curve for Anchor Cove shows no indication of leveling off (Fig. 75). Therefore, the species association on Mytilus-dominated plots was not adequately sampled there. These results support the conclusion that species

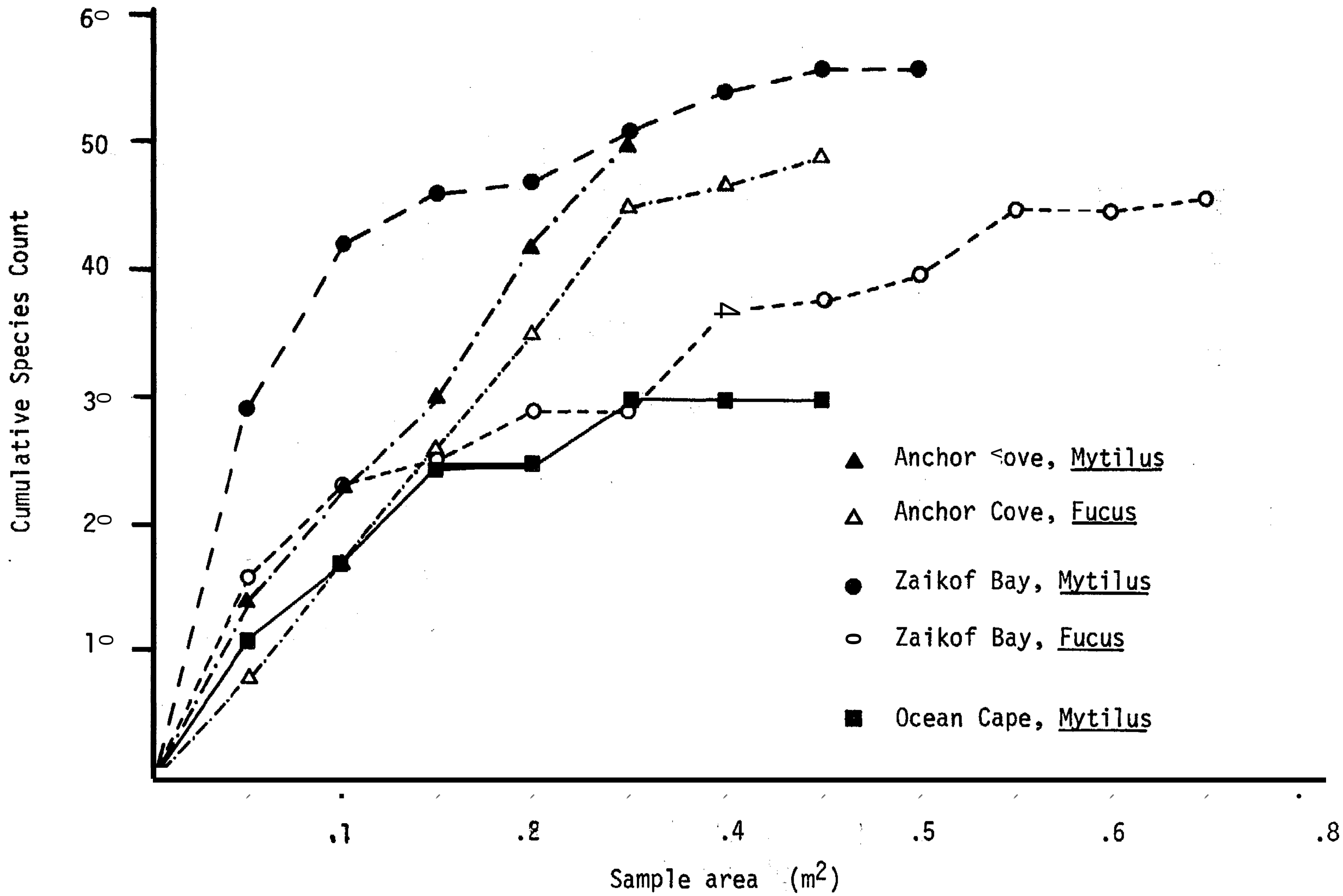


Fig.75. Species-area curves of plots dominated by *Mytilus* and *Fucus* at Anchor Cove, Zaikof Bay, and Ocean Cape.

Table 5. Smirnov test of differences in species-area curves in plots dominated by *Mytilus edulis* or *Fucus* spp. at Anchor Cove, Zaikof Bay, and Ocean Cape.

Contrast	Test Statistic*	Sample Size		Significance
	T1	N1	N2	
Mytilus				
Anchor Cove vs Ocean Cape	.400	5	7	n.s.
Zaikof Bay vs Ocean Cape	.875	7	8	$p < .005$
Fucus vs *Mytilus*				
Anchor Cove	,200	5	7	n.s.
Zaikof Bay	.659	8	11	$p < .025$

* All tests are one-sided.

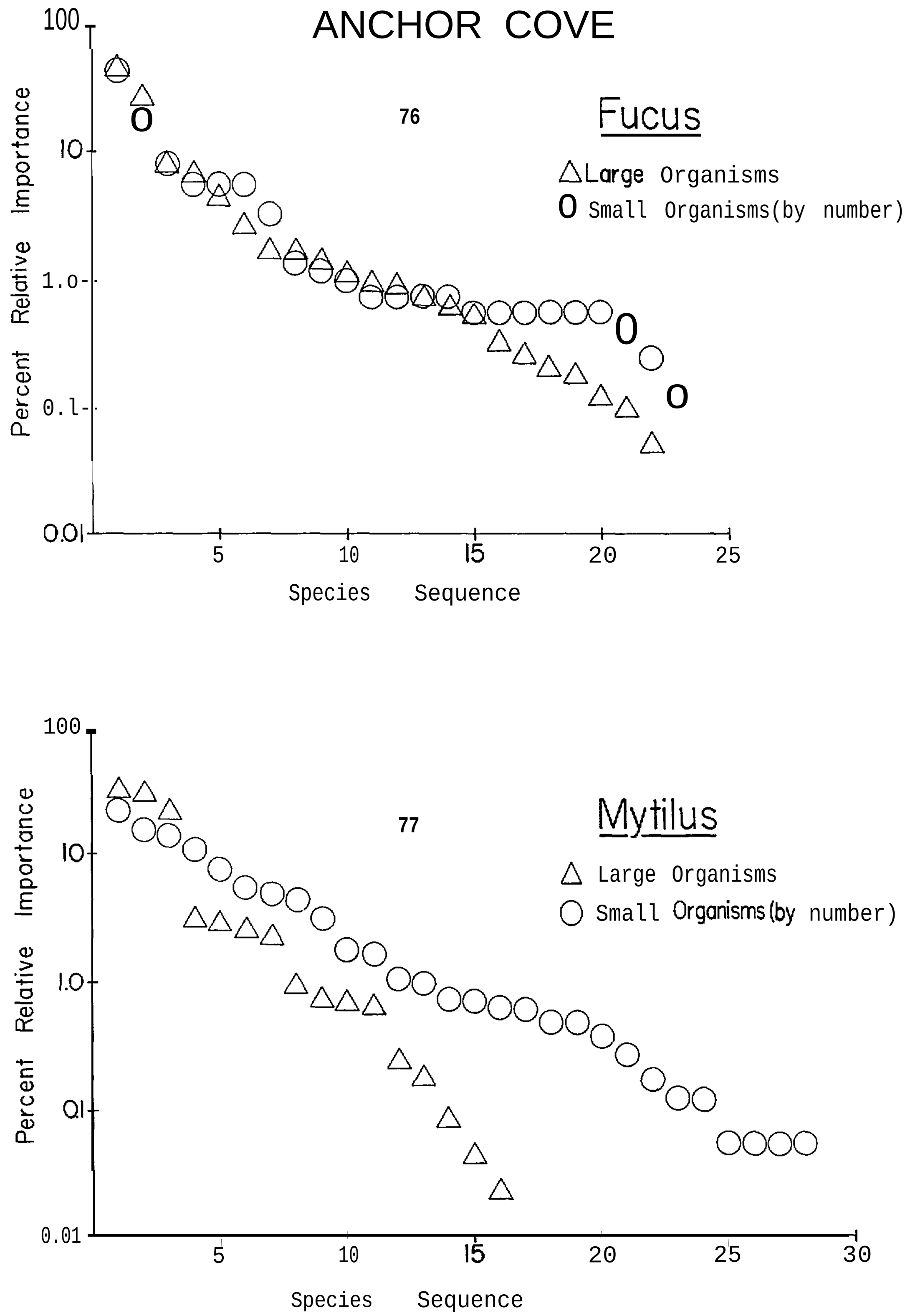
richness in the upper intertidal at Zaikof Bay (and probably also Anchor Cove) is greater than that at Ocean Cape.

Fig. 75 shows that the slopes and heights of the species-area curves for plots dominated by Mytilus at Zaikof Bay and Anchor Cove were greater than for those dominated by Fucus at the respective sites. This difference was significant for Zaikof Bay but not Anchor Cove (Table 5; the difference could not be tested at Ocean Cape because only two plots met the criteria for Fucus-dominated plots). An inadequate sample size (Mytil us-dominated plots) may have been responsible for the lack of significance in the test of the species-area curves of Mytilus-vs Fucus-dominated plots at Anchor Cove.

Species abundance relations

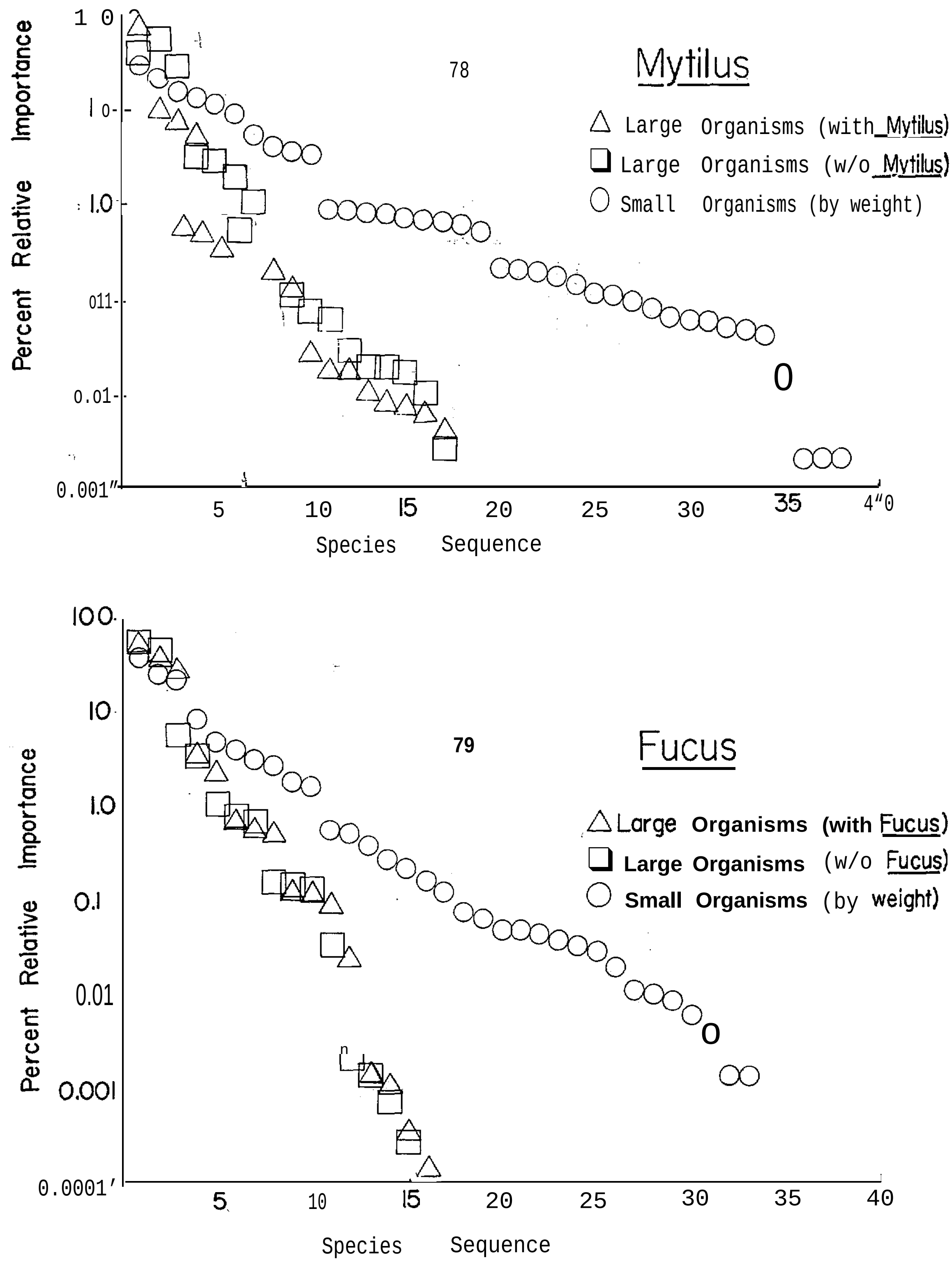
Dominance-diversity curves (Whittaker 1965, 1970, 1972) were used to study species-abundance relations among subdominant in Mytilus-and Fucus-dominated plots at Anchor Cove, Zaikof Bay, and Ocean Cape (Figs. 76 to 80). The curves are constructed by plotting the importance (in terms of abundance, biomass or productivity) of a species on the "y" axis opposite its respective rank on "x" axis. Species are ranked from most to least important on the "x" axis.

Subdominant were divided into large and small species based on the wet weight of an average adult; the dividing line was one gram. We distinguished between large and small species because a priori the former, because of their large body size, might be expected to suffer in competition for space with the dominants (Mytilus and Fucus), whereas the latter would "view" the holdfast, stipe and fronds of Fucus and the complex network of byssal threads and accumulated sediment beneath the shelter of Mytilus shells as elements of their physical environment. The hypothesis is that because of the different growth forms of the community dominants and the mechanisms by which they acquire and secure primary space (rock substratum) they will differ in their effect on subdominants,



Figs. 76 and 77. Relationship between relative importance (abundance or biomass expressed as a percentage on a logarithmic scale) and rank of large and small subdominant in plots dominated by *Fucus* (Fig. 76) or *Mytilus* (Fig. 77) at Anchor Cove, Alaska.

ZAIKOF BAY



Figs. 78 and 79. Relationship between relative importance (abundance and/or biomass expressed as a percentage on a logarithmic scale) and rank of large and small subdominant in plots dominated by Fucus (Fig. 78) or Mytilus (Fig. 79) at Zaikof Bay, Alaska.

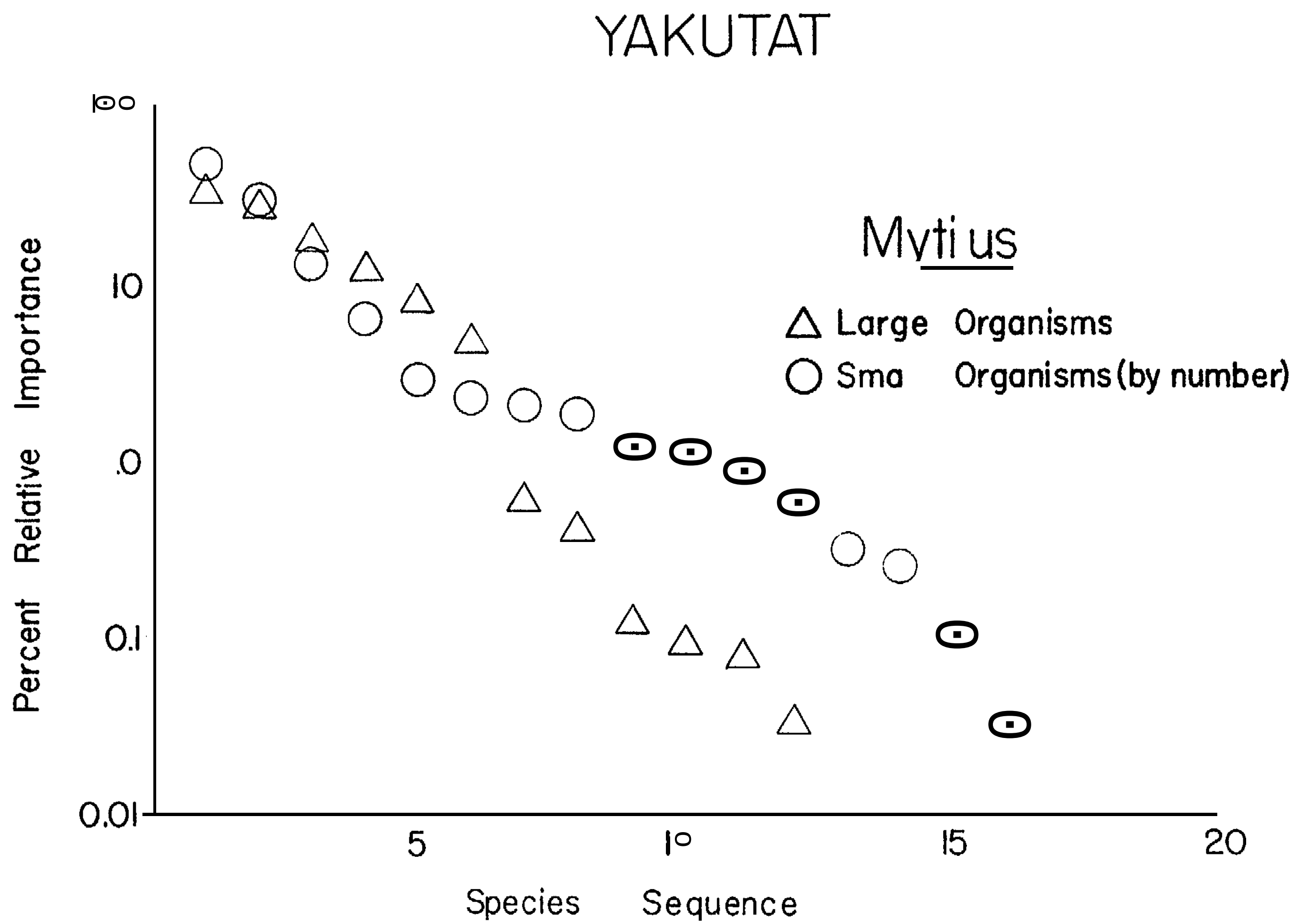


Fig. 80. Relationship between relative importance (abundance or biomass expressed as a percentage on a logarithmic scale) and rank of large and small subdominants in plots dominated by Mytilus at Ocean Cape, Yakutat, Alaska.

and that the difference should be reflected in the species abundance relations among subdominant.

Mytilus can completely blanket primary space and would be expected to have a greater negative effect on large subdominant than *Fucus* which has a small holdfast and a long narrow stipe. The holdfasts of adult *Fucus* usually do not pack primary space. *Fucus* would not be expected to adversely affect large subdominant other than those negatively affected by shad"ing or whiplash (Dayton 1971, Menge 1976).

Wet weight was used as a measure of importance among large subdominant in Figs. 76 to 80. Dominants (*Mytilus* and *Fucus*) were not included in the statistical analyses involving those plots which they were considered to dominate (e.g. *Fucus* was excluded from the analyses of *Fucus*-dominated plots). Curves of dominance-diversity among subdominants with and without dominants are shown in Figs. 78 and 79 for comparison; they are nearly identical..

The results from Anchor Cove tended to support the hypothesis. The curves for large subdominant in *Mytilus*-dominated plots show a lower species richness and greater concentration of dominance than those in *Fucus*-dominated plots (Figs. 76 and 77). However, the differences between the empirical distribution functions of the two curves was not significant (Table 6). Data from Zaikof Bay did not support the hypothesis (Figs. 78 and 79).

Abundance and wet weight were used as measures of importance of small subdominant in dominance-diversity curves for Anchor Cove and Zaikof Bay respectively (Figs. 76 to 79). In addition, curves of wet weights were drawn for the subdominant of Anchor Cove (not shown in Fig. 76). The curves of abundance and weights had the same form. Weights were used in the statistical analyses.

Species richness of small subdominant tended to be greater in *Mytilus* dominated plots than in *Fucus* dominated plots at Anchor Cove and Zaikof Bay,

Table 6 . Smirnov test of the differences in the empirical distribution functions of individuals among species in plots dominated by *Mytilus* and *Fucus* at Anchor Cove and Zaikof Bay.

Contrast	Test Statistic	Sample Size N1	Sample Size N2	Significance
Large subdominant				
Mytilus vs *Fucus*				
Anchor Cove	,210	16	22	nos.
Small subdominant				
Mytilus vs *Fucus*				
Anchor Cove	.228	36	30	n.s.
Zaikof Bay	.065	38	33	n.s.

but the form of the species-abundance curves was the same (Figs. 76 to 79). The Smirnov Test showed no significant difference between the curves for *Fucus* and *Mytilus* at either site (Table 6).

Multispectral Scanning

In June 1976 we began a cooperative study with the Environmental Research Institute (ERI) of Michigan to evaluate multispectral scanning (MSS) as a tool for mapping the distribution and abundance (aerial coverage) of littoral macrophytes from the air, Our role in the study was to map the vertical distribution of canopy macrophytes in the intertidal region and to compare the results with aerial MSS images of the region. Three sites were overflown during this study: Zaikof Bay, Latouche Point, and Cape Yakataga. At Latouche Point we used aluminum foil to delineate the boundaries of major zones dominated by macrophytes and to outline prominent landmarks prior to the scheduled over-flight of the MSS aircraft. Unfortunately the aircraft did not arrive as scheduled. The flight was completed 2 weeks later without the benefit of ground markers.

In August 1977 S. Zimmerman and J. Hanson met with ERI scientists in Ann Arbor, Michigan and assisted in selecting pure spectral signatures of major environmental features such as water, spruce trees and distinct algal zones to act as standards for “training the computer”, and to evaluate the classification of spectral signatures by the computer by comparing them with data from field observations.

The results were inconclusive. Interpretation of the MSS data was limited because there were no ground markers, the tide was not low enough, and the sky was overcast when the data were collected. The spectral signatures of major earth features such as water and spruce trees could be classified reliably, but the main objective of mapping the distribution and relative abundance of littoral macrophytes was not accomplished. Successful accomplishment of this objective will depend upon simultaneous collection of MSS and ground truth data.

VII. Discussion

Changes in species diversity measured in one way or another are commonly used to study the effects of human activities on natural communities (Jacobs 1975 reviews several studies). We consider two components of species diversity, species richness and the distribution of individuals among species: emphasizing especially the relationship between dominants and the diversity of subdominant in the intertidal community at upper levels. An understanding of this relationship is important to the study of the effects of perturbations (e.g. oil spills or shoreline development associated with offshore oil drilling) on intertidal communities if the degree to which potential community dominants can monopolize primary space differs from species to species and is functionally related to the diversity of subdominant. If this relationship exists then the effect of a perturbation on the diversity of a community would depend on which species dominates the community and how the perturbation affects the interactions between dominants and subdominant. Ultimately we would want to know what factors control populations of the community dominants.

Although higher species counts and higher and steeper species-area curves tended to be associated with relatively exposed bedrock sites where the frequency and scale of physical disturbance is low (Anchor Cove and Zaikof Bay) as opposed to exposed sites where physical disturbance is frequent and widespread (Ocean Cape and Cape Yakataga), the design of our study was inadequate for completely assessing the mechanisms controlling species diversity at these sites. Biological interactions (especially predation) may be important and were not adequately taken into account.

The relationship between the growth form of community dominants and the diversity of subdominant is not clear. Species richness (empirical distribution function of the species-area curve) was significantly greater in Mytilus-dominated plots than in Fucus-dominated plots at Zaikof Bay. Comparison of species-abundance patterns of large and small subdominant tended to indicate that the diversity of small subdominant was responsible for the difference but the trends were not significant. Similar trends were found for Anchor Cove, but none of the statistical tests were significant. An inadequate sample size at Anchor Cove is probably responsible for the lack of significance of at least one statistical test (of differences in species-area curves) of these trends.

There is little evidence to support the hypothesis that Mytilus has a greater negative effect on large subdominant than does Fucus. Large subdominant in Mytilus-dominated plots tended to show lower species richness and greater concentration of dominance than those in Fucus-dominated plots at Anchor Cove, but the results were not significant. There appeared to be no difference in slope or form of the species-abundance curves for Mytilus vs Fucus at Zaikof Bay.

VIII Conclusions

1. Frequent and widespread physical disturbance from boulder movement and ice scouring at Ocean Cape and Cape Yakataga offset the tendency for increased species richness in exposed localities. (Tentative)

2. Total species richness tends to be greater in patches of intertidal area dominated by Mytilus than in patches dominated by Fucus in the eastern Gulf of Alaska. (Preliminary)

3. Small species tend to be greater in number and show a greater evenness in the distribution of individuals among species in Mytilus- vs Fucus-dominated areas. (Preliminary)

4. Mytilus as a dominant competitor for space does not appear to have a greater adverse effect on associated larger subdominant through competition for primary space than does Fucus. (Preliminary)

5. The success of multispectral scanning (MSS) imagery for mapping the distribution of intertidal macrophytes requires the simultaneous collection of MSS and "ground truth" data. (Reasonably firm)

IX. Summary of Fourth Quarter Operations

A. No field trips were scheduled. The number and types of data analyses done this quarter are discussed in the methods and results sections of this report.

Milestone chart and data submission schedules

Milestone	Submission schedule Proposed	Submission schedule Actual
Completion of processed report on the Western Gulf of Alaska (Kodiak Island area)	January 1978	April 1978
Submission of rest of 1975 data to NODC	February 1978	April 1978
Completion of annual report with emphasis on EGOA	April 1, 1978	April 7, 1978
Submission of data from St. George Basin to NODC	July 1, 1978	
Completion of Quarterly Report with emphasis on St. George Basin	July 1, 1978	
Submission of data from Bristol Bay to NODC	October 1, 1978	
Completion of Quarterly Report with emphasis on Bristol Bay	October 1, 1978	
Submission of data from Norton Sound to NODC ,	3 months after reception of data from Institute of Marine Sciences (IMS)	
Completion of Quarterly Report with emphasis on Norton Sound	In that quarter which occurs 3 months after reception of data from IMS	

Justifications of Slippages

The completion of the processed report on the Western Gulf of Alaska (Kodiak Island area) was delayed because of unexpected resignations and resultant shortages in clerical staff. Submission of rest of 1975 data to NODC was delayed because of unanticipated difficulties with the emulators of the computer system used for OCS data and increased restrictions on access to that system.

B. Problems encountered/recommended changes

Broad surveys of intertidal communities aiming to characterize representative communities on the basis of the distribution and abundance patterns of component organisms with the hope of predicting community composition at unstudied locations are of dubious value as baseline studies for assessing the effects of human activities on natural communities. At best they provide a static view of some community attributes. Attempts to ask of the data from such surveys specific questions which might provide insight into those factors controlling community structure are often frustrated because the sampling programs are so broadly conceived that specific hypotheses cannot be adequately tested.

We need to take a more dynamic view of intertidal communities, to examine community organization and what controls it, in order to predict how oil or oil drilling activities will affect community structure. We have proposed studies to examine controlling mechanisms in intertidal communities with the ultimate goal of experimentally testing hypotheses in the field, but because of cuts in funding our proposal was not accepted. We are convinced that a more direct approach (involving the formulation and testing of specific hypotheses) to the question of how oil and gas development will affect the organization of nearshore communities is needed and urge that such an approach be adopted.

LITERATURE CITED

Anonymous 1964. United States Coast Pilot 9 Pacific and Arctic Coasts: Alaska, Cape Spencer to Beaufort Sea. 7th. ed. U.S. Government Printing Office, Washington, D.C. 347 p.

Anonymous 1976. Final environmental impact statement: Northern Gulf of Alaska. U.S. Department of the Interior, Bureau of Land Management, Alaska Outer Continental Shelf Office, Anchorage, Alaska. 466 p.

Bertness, M.D. 1977; Behavioral and ecological aspects of shore-level size gradients in Thais lamellosa and Thais emarginata. Ecology 58:86-97.

Bloom, Stephen A. 1974. Resource partitioning among doridacean nudibranch molluscs of the San Juan Archipelago, Washington. A guild hypothesis. Ph. D, dissertation, Univ. Wash.

Connell, J.H. 1970. A predator-prey system in the marine intertidal region. I. Balanus glandula and several predatory species of Thais. Ecol. Monogr. 40:49-78.

Connell, J.H. 1972, Community interactions on marine rocky intertidal shores. Ann. Rev. of Ecol. and Syst. 3:169-192.

Connell, J.H. 1975. Some mechanisms producing structure in natural communities: a model and evidence from field experiments. pp. 460-490. In: M.L. Cody and J.M. Diamond (eds.). The ecology and evolution of communities. Harvard University Press, Cambridge, Massachusetts. 624 p.

Conover, W.J. 1971. Practical nonparametric statistics. Wiley, New York 474 p. "'

Dayton, P.K. 1971. Competition, disturbance, and community organization: The provision and subsequent utilization of space in a rocky intertidal community. Ecological Monographs 41:351-389.

Evans, J.W. 1968. The role of Penitella penita (Conrad 1837) (Family Pholadidae) as eroders along the Pacific Coast of North America. Ecology 49:156-159.

Feder, H.M., and G. Mueller 1972. The intertidal region of the Gulf of Alaska Section 4 75-130. In: A review of the oceanography and renewable resources of the northern Gulf of Alaska. D.H. Rosenberg, ed. Institute of Marine Sciences, University of Alaska, Fairbanks. Report R72-23. 700 p.

Glynn, P.W. 1965. Community composition, structure, and interrelationships in the marine intertidal Endocladia muricata-Balanus glandula association in Monterey Bay, California. Beaufortia, 12:1-198.

Goodman, D. 1975. The theory of diversity-stability relationships in ecology. Quart. Rev. Biol. 50(3):237-266.

Gray, J. 1976. Are marine baseline surveys worthwhile? New Scientist 70:219-221.

Guiry, M.D. 1974. A preliminary consideration of the taxonomic position of Palmaria palmata [Linnaeus] Stackhouse = Rhodymenia palmata [Linnaeus] Greville. J. mar. biol. Ass. U.K. 54:509-528.

Gurjanova, E.F. 1935. Komandorskie ostrova i ikh morskaya pribezhnaya faunai flora (The Commander Islands, their littoral fauna and flora). Priroda, No. 11: 64-72. (Transl. from Russian by Leda V. Sagen).

Gurjanova, E. F. 1966. Comparative research of biology of the littoral in the Far Eastern seas. Proc. Ninth Pac. Sci. Congr. 19 (zoology):75-86.

Hanna, G.D. 1971. Introduction: biological effects of the earthquake as observed in 1965. pp. 15-34. In: the Great Alaska Earthquake of 1964: Biology. NAS Pub. 1604, National Academy of Sciences, Washington, 302 p.

Haven, S.B. 1971. Effects of land-level changes on intertidal invertebrates, with discussion of post-earthquake ecological succession. pp. 82-126 In: The Great Alaska Earthquake of 1964: Biology. NAS Pub. 1604. National Academy of Sciences, Washington. 302 p.

Hurlbert, S.H. 1971. The nonconcept of species diversity: a critique and alternative parameters. Ecology 52:577-586.

Hyman, L.H. 1951. The invertebrates: Platyhelminthes and Rhynchocoela, the acoelomate Bilateria Vol. 2. McGraw-Hill, New York 557 p.

Jacobs, J. 1975. Diversity, stability and maturity in ecosystems influenced by human activities. pp. 187-207 in Unifying concepts in ecology (eds.) W. H. Van Dobben and R.H. Lowe-McConnell. Dr. W. Junk, B.V. Publishers the Hague. 302 p.

Johansen, H.W. 1971. Effects of elevation changes on benthic algae in Prince William Sound. pp. 35-68. In: The Great Alaska Earthquake of 1964: Biology. NAS Pub. 1604, National Academy of Sciences, Washington 302 p.

Landenberger, D.E. 1968. Studies on selective feeding in the Pacific starfish Pisaster in southern California. Ecology 49:1062-1075.

Lebednik, P.A. and J.F. Palmisano. 1977. Ecology of marine algae pp. 353-393. In: M.L. Merritt and R.G. Fuller (eds.). The environment of Amchitka Island, Alaska 694 p.

Levin, S.A. and R.T. Paine. 1974. Disturbance, patch formation and community structure. Proc. Nat. Acad. Sci. U.S.A. 71:2744-2747.

Lewis, J.R. 1964. The ecology of rocky shores. The English Universities Press Ltd., London, 335 p.

Lewis, J.R. 1972. Problems and approaches to baseline studies in coastal communities, p. 401-404. In: M. Ruivo (cd,) Marine Pollution and Sea Life Fishing News (Books) Ltd.

Mauzey, K.P. 1966, Feeding behavior and reproductive cycles. in Pisaster ochraceus. Biol. Bull. 131:127-144.

Mauzey, K.P., C. Birkeland, and P.K. Dayton. 1968. Feeding behavior of asteroids and escape responses of their prey. in the Puget Sound region. Ecology 49:603-619.

May, R.M. 1975. Patterns of species abundance and diversity, pp. 81-120. In: Cody, M.L. and J.M. Diamond, (eds.), The ecology and evolution of communities. Harvard University Press, Cambridge, Massachusetts. 624 pp.

Menge, B.A. 1976. Organization of the New England rocky intertidal community: role of predation, competition, and environmental heterogeneity. Ecol. Monogr. 46:355-393.

Moffit, F.H. 1954. Geology of the Prince William Sound region, Alaska. U.S. Geol. Survey Bull. 989-E, p. 225-310.

Moore, H.B. 1938. The biology of Purpura lapillus. Part III. Life history and relation to environmental factors. J. mar. biol. Ass. U.K. 23:67-74.

Munda, I. 1972. On the chemical composition, distribution and ecology of some common benthic marine algae from Iceland. Botanica Marina 15:1-45.

Nelson-Smith, A. 1972. Oil pollution and marine ecology. Elek. Science, London 269 pp.

Neuhold, J.M. and L.F. Ruggerio. 1976. Ecosystem Processes and Organic Contaminants: Research needs and an interdisciplinary perspective. U.S. Government Printing Office, Washington, D.C. 52 p.

North, W.J., Neushul, M. and Clendenning, K.A. 1964. Successive biological changes observed in a marine cove exposed to a large spillage of mineral oil. Symp. Poll. mar. Micro-org. Prod. petrol, Monaco, 335-354.

Northcraft, R. D. 1948. Marine algal colonization on the Monterey Peninsula, California. Am. J. Bet. 35:396-404.

Nybakken, J.W. 1969. Pre-earthquake intertidal ecology of Three Saints Bay, Kodiak Island, Alaska. Biol. Papers of the University of Alaska 9:123 p.

Paine, R.T. 1966. Food web complexity and species diversity. Amer. Natur. 100:65-75.

Paine, R.T. 1971. A short-term experimental investigation of resource partitioning in a New Zealand rocky intertidal habitat. Ecology 52:1096-1106.

Paine, R.T. 1974. Intertidal community strucutre: experimental studies on the relationship between a dominant competitor and its principal predator. Oecologia 15:93-120.

Paine, R.T. 1976. Size-limited predation: An observational and experimental approach with the Mytilus-Pisaster interaction, Ecology 57:858-873.

Palmisano, J.F. Accumulation rate of drift biota on three beaches in the eastern Gulf of Alaska (in prep.).

Peet, R.K. 1974. The measurement of species diversity. Ann. Rev. Ecol. and Syst. 5:285-307.

Rigg, G.B., and R.C. Miller, 1949. Intertidal plant and animal zonation in the vicinity of Neah Bay, Washington. Proc. Cal. Acad. of Sci. 26:323-351.

Rosenthal, R.J., D.C. Lees and T.M. Rosenthal. 1977. Ecological assessment of sublittoral plant communities in the northern Gulf of Alaska for National Marine Fisheries Service, Auke Bay Laboratory. Final Report. Dames & Moore, Anchorage, Ak. 150 pp.

Sears, H.S. and S.T. Zimmerman. 1977. Alaska Intertidal Survey Atlas. Northwest and Alaska Fisheries Center Auke Bay Laboratory, Auke Bay, Ak. 385 pp.

Smith, J.E. (cd.) 1968. "Torrey Canyon" Pollution and Marine Life. Cambridge University Press, London 210 p.

Southward, A.J. and E.C. Southward. 1978. The recolonization of rocky shores in Cornwall after use of toxic dispersants to clean-up the "Torrey Canyon" spill. J. Fish. Res. Board Can. (in press; abstract only seen).

Spight, T.M. 1976. Just another benthic study. Ecology 57:622-623.

Stephenson, T.A. and A. Stephenson. 1972. Life Between Tidemarks on Rocky Shores. W.H. Freeman & Co., San Fracisco. 425 p.

Whittaker, R.H. 1965. Dominance and diversity in land plant communities. Science 147:250-260.

Whittaker, R. H. 1970. Communities and Ecosystems. The Mac Millan Company, New York 158 pp.

Whittaker, R.H. 1972. Evolution and measurement of species diversity. Taxon 21: 213-251.

Zimmerman, S.T. and T.R. Merrell, Jr. 1976a. Baseline/ reconnaissance characterization littoral biota, Gulf of Alaska and Bering Sea. Quarterly Report April 1- June 30, 1976, Outer Continental Shelf Energy Assessment Program. 52 pp.

Zimmerman, S.T. and T.R. Merrell, Jr. 1976b. Baseline characterization, littoral biota, Gulf of Alaska and Bering Sea. Final Report July 1, 1975-March 31, 1976, Outer Continental Shelf Energy Assessment Program 53 p.

Zimmerman, S.T., J.L. Hanson, J.T. Fujioka, N.I. Calvin, J.A. Gharrett, J.S. MacKinnon. 1978. Intertidal biota and subtidal kelp communities of the Kodiak Island area, Northwest and Alaska Fisheries Center Auke Bay Laboratory; National Marine Fisheries Service, NOAA, Auke Bay, Alaska Processed Report 180 p.

Appendix 1. Presence (x) or absence (blank) of species of plants, invertebrates, and fish in the rocky intertidal area at eleven sites in the eastern Gulf of Alaska.

SPECIES	Ocean Cape	Cape Yakataga	Katalla Bay	Cape St Elias	Port Etches	Zaikof Bay	Macleod Harbor	Squirrel Bay	Latouche Point	Anchor Cove	Gore Point
CHLOROPHYTA											
Chlorophyta	x	x	x		x	x	x	x	x	x	x
Ulothrix sp.		x			x	x	x	x		x	x
Monostroma sp.		x		x		x			x	x	x
Monostroma arcticum					x						
Monostroma fuscum	x	x	x	x	x	x	x	x	x	x	x
Monostroma zostericola		x		x	x	x	x			x	
Enteromorpha sp.		x								x	
Enteromorpha intestinalis	x	x					x		x	x	x
Enteromorpha linza		x			x	x	x			x	
Ulva sp.	x	x	x			x		x		x	x
Ulva fenestrata				x	x	x	x	x		x	x
Ulva lactuca		x	x	x	x	x	x	x	x	x	x
Ulva rigida						x	x			x	
Percursaria percursa	x									x	
Rosenvingiella sp.											x
Rosenvingiella polyrhiza											x
Cladophoraceae				x							
Rhizoclonium sp.						x					
Rhizoclonium implexum						x					
Rhizoclonium riparium	x	x		x	x	x	x		x	x	
Lola lubrica	xx	x				x	x				x
Urospora sp.				x		x					x
Urospora mirabilis	x	x				x	x				x
Chaetomorpha sp.		x				x					
Chaetomorpha cannabina										x	
Cladophora sp.	x	x	x		x	x				x	
Cladophora flexuosa			x		x		x		x	x	
Cladophora gracilis						x					
Cladophora seriacea	x				x	x			x	x	
Spongomorpha sp.				x			x				
Spongomorpha mertensii				x						x	
Spongomorpha spinescens	x	x		x		x				x	x
Codium fragile		x	x								
Halicystis ovalis			x								
CRYSOPHYTA											
Crysophyta	x					x	x				x
Bacillariophyceae		x		x	x	x			x	x	
Centrales											

SPECIES	Ocean Cape	Cape Yakataga	Katalla Bay	Cape St Elias	Port Etches	Zaikof Bay	Macleod Harbor	Squirrel Bay	Latouche Point	Anchor Cove	Gore Point
CRYSOPHYTA-continued											
Isthmia nervosa			X								
Navicula sp.			X				X			X	
PHAEOPHYTA	X	X	X	X	X	X	X	X	X	X	X
Ectocarpales		X									
Ectocarpaceae						X					
Ectocarpus sp.	X	X		X		X					
Ectocarpus parvus		X		X							
Ectocarpus siliculosus										X	
Ectocarpus simulans	X	X		X	X	X	X		X	X	
Pylaiella littorals	X	X	X		X	X	X	X	X	X	X
Ralfsiaceae				X							
Ralfsia sp.			X	X							
Ralfsia fungiformis			X	X	X	X			X		
Ralfisa pacifica		X									
Sphacelaria sp.	X	X				X	X				X
Sphacelaria subfusca						X	X			X	
Elachistea fucicola		X				X	X	X	X	X	X
Leathesia difformis						X					
Haplogloia andersonii		X									
Chordaria sp.		X									
Chordaria flagelliformis		X									
Analipus japonicus		X									X
Desmarestia aculeata			X				X				
Soranthera ulvoidea		X				X	X		X	X	
Melanosiphon intestinal		X				X					X
Petalonia sp.		X									
Petalonia fascia		X	X				X	X			
Colpomenia bullosa				X							
Phaestrophion irregulare				X							
Scytosiphon sp.						X					
Scytosiphon lomentaria	X	X	X		X	X	X		X	X	I
Coilodesme sp.		X									
Laminaria sp.		X				X			X	X	
Laminaria groenlandica		X	X	X		X			X	X	
Laminaria saccharin			X			X			X		
Laminaria setchellii			X		X				X	X	
Laminaria yezoensis			X	X		X			X		
Alaria sp.	X	X	X	X	X	X	X	X	X	X	X
Alaria crisps								X			
Alaria marginata		X		X	X	X	X	X	X	X	X

Appendix 1 . Continued

SPECIES	Ocean Cape	Cape Yakataga	Katalla Bay	Cape St Elias	Port Etches	Zaikof Bay	Macleod Harbor	Squirrel Bay	Latouche Point	Anchor Cove	Gore Point
PHAEOPHYTA-continued											
Alaria nana	X					X				X	
Alaria praelonga						X	X	X		X	
Alari . . .	X					X	X		X	X	X
Fucus sp.	X	X	X	X		X	X		X	X	X
Fucus distichus	X	X	X			X	X	X	X	X	X
Fucus spiralis	X	X								X	
Cystoseira geminata					X						
RHODOPHYTA		X	X	X	X	X	X		X	X	X
Erythrotrichea sp.		X									
Erythrotrichea carmea						X					
Smithora naiadum			X								
Bangia fuscopurpurea										X	
Porphyra sp.	X	X	X			X	X	X	X	X	X
Porphyra perforata		X	X		X		X	X		X	
Porphyra smithii									X		
Acrochaetium sp.				X		X					X
Acrochaetium pacificum						X					
Cryptonemiales						X					
Cryptosiphonia sp.						X					
Cryptosiphonia woodii		X	X	X	X	X	X		X	X	X
Dilsea californica				X							X
Dumontia incrassata						X	X				
Farlowia compressa							X				
Constantinea sp.							X				
Constantinea simplex				X	X				X		
Constantinea subulifera				X		X			X		
Endocladia muricata	X						X		X	X	X
Gloiopeltis sp.						X				X	
Gloiopeltis furcata				X		X	X	X		X	X
Peyssonellia pacifica							X				
Hildenbrandia sp.			X								
Petrocelis sp.										X	X
Petrocelis franciscana											X
Corallinaceae			X	X			X		X		
Tenarea dispar						X					
Mesophyllum sp.			X						X		
Mesophyllum lamellatum											
Clathromorphum sp.				X							

SITES

SPECIES	Ocean Cape	Cape Yakataga	Katalla Bay	Cape St Elias	Port Etches	Zaikof Bay	Macleod Harbor	Squirrel Bay	Latouche Point	Anchor Cove	Gore Point
RHODOPHYTA-continued											
Bossiella sp.			x	X		x	X	x	X	x	x
Bossiella californica					x		X				
Bossiella chiloensis	x		X		x	x	x		x	x	
Bossiella plumosa			x	X		X 1	X		x	X	
Serraticardia macmillani				x							
Corallina sp.				X	X	X	X		X	X	
Corallina officinalis				X							
Corallina vancouveriensis				X		X			X		
Corallina frondescens						X	X				
Lithothamnium sp.		X	X	X		X			X	X	
Cryptonemiaceae				"X							
Prionitis sp.							X				
Prionitis lanceolata										X	
Pugetia fragilissima								x			
Callophyllis sp.							X				x
Callophyllis adhaerens								x			
Callophyllis flabellulata		X				X	x	"X		X	X
Gigartinales									X		
Neoagardhiella baileyi		x					x				
Plocamium tenue									X		
Ahnfeltia plicata			X	X		x			X	X	X
Ahnfeltia gigartinoides			X						X		
Gymnogongrus platyphyllus								X			
Gigartinaceae							x		x		
Gigartina sp.	X	X				X		x		X	X
Gigartina papillata		X	X		x		X	X	X	x	
Gigartina agardhii						X					
Gigartina latissima	X	x	x		X			x	x	x	
Gigartina stellata		x				X			x	x	X
Iridaea sp.	X	x	x	x		X	X	X	X	X	x
Iridaea cordata						X				X	
Iridaea cornucopia		x		x	X1X		X	x	X	X	x
Iridaea heterocarpa						x	X	x	X	X	x
Iridaea lineare			X								
Rhodoglossum californicum	X		X		X	X	X	X	X	X	
Rhodymeniaceae										X	
Fauchea laciniata										X	
Halosaccion glandiforme	t	x	x	L x "	'	X	x	X	X	X	X
hodymenia liniformis					X			X			
Rhodymenia sp.								X		X	

Appendix 1 . Continued

SPECIES	Ocean Cape	Cape Yakataga	Katalla Bay	Cape St Elias	Port Etches	Zaikof Bay	Macleod Harbor	Squirrel Bay	Latouche Point	Anchor Cove	Gore Point
	SITES										
RHODOPHYTA-continued											
Palmaria palmata	x	x	x	x	x	x	x	x	x	x	x
Rhodymenia pertusa			x		X		x		x	x	
Ceramiaceae									x	x	
Antithamnion sp.					I I	xl	xl			x	
Antithamnion dendroideum						x					
Antithamnion kylinii	x				x	X	X	X		x	
Antithamnion simulans						X					
Antithamnionella pacifica					x		x			X	
Scagelia occidentale						x				X	
Hollenbergia nigricans						x					
Callithamnion pikeanum	x						x			X	
Ceramium pacificum				x l							
Microcladia borealis				x					x		X
Microcladia coulteri									x		
Ptilota sp.					x	x		x	X	X	X
Ptilota filicina					X	x		x	X	X	X
Ptilota tenuis					x	x	x		X		
Neoptilota sp.							x		X	X	X
Neoptilota asplenioides				X	X	X	X	X	X	X	X
Neoptilota hypnoides			X			x				X	
Delesseriaceae			X			X	X			X	X
Tokidadendron sp.						X	X			X	
Tokidadendron bullata					X	X	X			X	X
Phycodrys sp.						x				X	
Phycodrys riggii						X					
Hypophyllum sp.						X					
Hypophyllum dentatum						X					
Rhodomelaceae		X		X			X		X	X	X
Polysiphonia sp.						X			X	X	
Polysiphonia hendryi			x	X	X	X	x		X	X	
Polysiphonia pacifica	X				X	x	x			X	
Pterosiphonia sp.			x	x		x	X			X	
Pterosiphonia arctica	X						X			X	
Pterosiphonia bipinnata	X	X	X	x		x	x	X	X	X	X
Pterosiphonia dendroidea										X	
Laurencia spectabilis	x										
Rhodomela sp.						x					
Rhodomela larix	x	X	X	X	X	X	X		x	X	
Odonthalia sp.	X	X	X	X		X	x		X	X	X

Appendix 1 . Continued

SPECIES	Ocean Cape	Cape Yakataga	Katalla Bay	Cape St Elias	Port Etches	Zaikof Bay	Macleod Harbor	Squirrel Bay	Latouche Point	Anchor Cove	Gore Point
RHODOPHYTA-continued											
Odonthalia aleutica								x		x	
Odonthalia floccosa	x	x	x	x	x	x	x	x	x	x	x
Odonthalia kamschatica						x				x	
donthalia lyallii										x	
Odonthalia washingtoniensis	x		x		x	x	x		x	x	x
PHYCOMYCETES											
Phycomycetes		x	x			x	x				
ANTHOPHYTA											
Monocotyledoneae									x		
Potamogetonaceae				x					x		
Phyllospadix sp.				x	x	x	x		x		
Zostera marina	x										
PORIFERA											
Demospongia	x		x	x	x	x	x	x	x	x	x
CNIDARIA											
Hydroidea	x	x				x				x	x
Clava multiforms											x
Eudendrium sp.	x									x	
Eudendrium annulatum	x	x									
Eudendrium ramosum							x				
Obelia sp.											x
Sertulariidae							x				
Sertularella tricuspidata		x									
Abietinaria sp.		x									
Anthozoa		x	x	x	x	x	x	x	x	x	x
Anthopleura sp.			x			x					
Tealia sp.			x								
TURBELLARIA											
Turbellaria	x	x	x	x	x	x	x	x	x	x	x
RHYNCHOCOELA											
Rhynchocoela	x	x	x	x	x	x	x	x	x	x	x
Emplectonema sp.		x									
Emplectonema gracile	x	x	x		x	x	x	x	x	x	x

Appendix 1 . Continued

SPECIES	Ocean Cape	Cape Yakataga	Katalla Bay	Cape St. Elias	Port Etches	Zaikof Bay	Macleod Harbor	Squirrel Bay	Latouche Point	Anchor Cove	Gore Point
NEMATODA											
Nematoda		X	X	X	X	X	X	X	X	X	
ANNELIDA											
Annelida		X				X				X	
Polychaeta		X		X	X	X	X		X		X
Polynoidae						X			X	X	
Gattyana ciliata									X		
Halosydna brevisetosa				X					X		
Harmothoe sp.						X					
Harmothoe imbricata			X	X	X	X			X	X	
Lepidonotus squamatus			X			X			X		
Pholoe minuta	X		X			X				X	
Paleonotus bellis										X	
Dysponetus sp.											
Phyllodocidae		X		X	X	X	X		X	X	X
Anaitides maculata				X		X					
Eteone sp.		X									X
Eteone pacifica		X	X		X	X	X			X	
Eteone longa		X	X				X			X	X
Eulalia sp.				X				X	X		X
Eulalia viridis		X		X		X	X	X		X	
Eulalia bilineata											X
Eulalia quadrioculata	X	X		X		X	X		X	X	X
Notophyllum imbricatum					X						
Genetyllis castanea					X					X	
Syllidae				X		X	X			X	X
Autolytus sp.		X		X		X			X	X	X
Autolytus cornutus	X									X	
Autolytus prismaticus					X	X			X	X	
Typosyllis sp.	X	X	X	X			X	X	X	X	X
Typosyllis alternata	X	X	X		X	X	X	X	X	X	X
Typosyllis armillaris									X	X	
Typosyllis pulchra	X	X	X			X	X	X	X	X	X
Typosyllis stewarti					X		X		X	X	
Typosyllis fasciata	X	X	X				X	X	X	X	
Typosyllis a. adamantea	X	X	X			X	X	X	X	X	X
Typosyllis harti	X										
Typosyllis hyalina				X						X	
Eusyllis sp.										X	
Eusyllis assimilis							X				

Appendix 1, Continued

SPECIES	Ocean Cape	Cape Yakataga	Katalla Bay	Cape St. Elias	Port Etches	Zaikof Bay	Macleod Harbor	Squirrel Bay	Latouche Point	Anchor Cove	Gore Point
ANNELIDA-continued											
Eusvllis blomstrandi							x				
Exogone sp.				x					x		
Exogone gemmifera			x	x		x			x	x	x
Exogone lourei				x		x			x		
Exogone molests				x					x		
Exogone verrugera		x		x			x		x	x	
Sphaerosyllis sp.				x			x		x	x	x
Sphaerosyllis hystrix						x				x	
Sphaerosyllis pirifera											x
Brania brevipharyngea							x				
Brania clavata										x	
Odontosyllis parva									x		
Odontosyllis phosphorea										x	
yllides japonica						x			x		
Nereidae		x									
Nereis sp.	x	x	x	x	x	x	x	x	x	x	x
Nereis pelagica			x	x		x	x		x	x	x
Nereis procera			x		x	x	x		x	x	
Nereis vexillosa	x	x	x	x		x	x		x	x	x
Nereis zonata									x	x	
Nereis grubei										x	
Platynereis bicanaliculata						x				x	
Nephtys sp.						x					
Nephtys cornuta									x		
Spaerodoridium gracilis						x	x				
Sphaerodoropsis minutum				x		x	x		x		
Glyceride										x	
Glycera capitata							x				
Glycinde picta						x		x	x		
Onuphis sp.									x		
Onuphis geofiliformis									x		
Onuphis iridescent									x		
Onuphis stigmatis									x		
Eunicidae									x		
Eunice sp.									x		
Eunice valens						x			x		
Eunice kobiensis									x		
Lumbrineridae						x			x		
Lumbrineris sp.				x					x		
Lumbrineris similabris									x		

Appendix 1 . Continued

SPECIES	Ocean Cape	Cape Yakataga	Katalla Bay	Cape St. Elias	Port Etches	Zaikof Bay	Macleod Harbor	Squirrel Bay	Latouche Point	Anchor Cove	Gore Point
ANNELIDA-continued											
Lumbrineris zonata						X	X		X		
Lumbrineris japonica	X								X		
Lumbrineris inflata				X	X	X			X	-X	
Haploscoloplos elongatus					X				X		
Naineris sp.				X							
Naineris dendritica									X		
Naineris quadricuspida				X					X		
Naineris laevigata				X					X		
Aricidea suecica								X			
Tauberia gracilis							X				
Spionidae		X	X	X	X	X	X		X	X	
Polydora sp.			X	X	X	X			X		
Polydora ciliata	X					X	X				
Prionospio cirrifera										X	
Spio filicornis		X	X		X	X	X	X	X	X	
Boccardia sp.									X		
Boccardia columbiana						X	X	X	X	X	
Boccardia natrix		X					X				
Boccardia proboscidea						X				X	
Spiophanes bombyx			X				X				
Spiophanes cirrata							X				
Rhynchospio sp.		X	X								
Pygospio sp.		X									
Pygospio elegans		X					X		X		
Cirratulidae			X								
Cirratulus cirratus	X		X	X		X	X		X	X	X
Caulleriella sp.						X	X				
Tharyx sp.				X		X			X	X	
Brada villosa							X			X	
Pherusa papillata						X				X	
Opheliidae						X					
Ammotrypane aulogaster									X		
Armandia brevis						X					
Ophelia limacina				X							
Capitellidae		X									
Capitella sp.										X	
Capitella capitata		X	X		X	X	X	X		X	
Heteromastus filiformis										X	
Abarenicola pacifica						X					

Appendix 1 . Continued

SPECIES	Ocean Cape	Cape Yakataga	Katalla Bay	Cape St. Elias	Port Etches	Zaikof Bay	Macleod Harbor	Squirrel Bay	Latouche Point	Anchor Cove	Gore Point
ANNELIDA-continued											
Maldanidae			x		I	I			x	I	I
Nicomache lumbricalis									x		
Nicomache personata			x						x		
Axiothella rubrocincta									x		
Praxillella affinis									x		
Owenia fusiformis			x								
Myriochele heeri			x								
Cistenides brevicoma					x	x	x		1"		
Pectinaria belgica					x		x		'1		
Ampharetidae						x					
Ampharete arctica						x			xl		
Asabellides sibirica		x				x	x		x		
Nicolea zostericola						x					
Polycirrus caliendrum						x					
Polycirrus medusa									x		
Terebellides stroemi									x		
Sabellidae		x			I	lx		x			
Chone gracilis		x							x		x
Chone infundibuliformis		x									
Potamilla sp.		x							x		
Potamilla neglecta					i !				x		
Pseudopotamilla reniformis 1	x										
Schizobranchia insignis			x						x		
Amphiglena pacifica									x		x
Fabricia sabella		x		xl		ix		x	x	x	x
Fabricia minuta 2					I I			x	x	x	
Fabricia pacifica 3	x								x		
Fabricia crenicollis		x		x							x
Laonome sp.							x	xl			
Serpulidae			x						x		
Serpula vermicularis						,x I					
Laeospira granulates										x	
Dexiospira spirillum				x	x	x	x		x	x	x
Oligochaeta	x	x	x	x		x	x				x
Enchytraidae	x	x	x		x	x	x	x	x	x	
MOLLUSCA											
Mollusca	x					x	x	x			xl
Polyplacophora		x			x	x				x	

1 Banse = Potamilla intermedia (Moore)

2 Banse = Oriopsis minuta (Berkeley and Berkeley)

3 Banse = Fabriciola berkeleyi Banse

Appendix 1. Continued

SPECIES	Ocean Cape	Cape Yakataga	Katalla Bay	Cape St. Elias	Port Etches	Zaikof Bay	Macleod Harbor	Squirrel Bay	Latouche Point	Anchor Cove	Gore Point
MOLLUSCA-continued											
Cynoplax sp.										x	
Cynoplax dentiens				x		x			x	x	
Tonicella lineata			x		x	x	x		x	x	
Tonicella marmorea					x						
Tonicella rubra							x			x	
Dendrochiton thamnopora						x					
Katharina tunicata	x			x	x	x	x	x	x	x	x
Mopalia sp.	x					x				x	
Mopalia cirrata										x	
Mopalia ciliata		x			x	x	x		x	x	
Mopalia lignosa										x	
Mopalia muscosa											
Mopalia sinuata										x	
Schizoplax brandtii			x					x	x	x	
Hanleya hanleyi							x				
Pelecypoda	x		x	x		x			x		
Nucula tenuis								x		x	
Nuculana pernula										x	
Mytilus edulis	x	x	x	x	x	x	x		x	x	x
Musculus sp.			x			x			x		x
Musculus niger						x					
Musculus discors					x	x	x	x	x	x	x
Musculus vernicosus						x	x				
Dacrydium sp.						x			x	x	
Modiolus modiolus			x	x		x			x	x	x
Pododesmus macroschisma						x					
Axinopsida serricata											
Mysella planata			'1						x		
Turtonia minuta						x			x		x
Turtonia occidentals				x		x	x		x		x
Saxi-domus gigantea										x	
Protothaca sp.			x			x					
Protothaca staminea		x	x	x	x	x	x		x	x	x
Macoma sp.			x			x	x				
Macoma balthica			x		x	x	x		x		
Mya sp.		x									
Mya arenaria			x								
Cyrtodaria kurriana						x					
Hiatella sp.						x					
Hiatella arctica	x		x	x	x	x	x	x	x	x	x
Hiatella striata											

Appendix 1 . Continued

SPECIES	Ocean Cape	Cape Yakataga	Katalla Bay	Cape St. Elias	Port Etches	Zaikof Bay	Macleod Harbor	Squirrel Bay	Latouche Point	Anchor Cove	Gore Point
MOLLUSCA-continued											
Entodesma saxicola	X										
Thracia sp.						X					
Gastropod	X	X	X	X		X		X	X	X	X
Puncturella sp.							X				
Puncturella cucullata							X				
Acmaeidae											
Acmaea sp.		X					X			X	
Acmaea mitra				X							
Acmaea rosacea							X				
Collisella sp.		X	X			X			X	X	X
Collisella.pelts	X		X	X	X	X	X	X	X	X	X
Collisella digitalis	X		X			X	X		X	X	X
Collisella ochracea						X					
Notoacmea scutum	X	X	X	X				X	X	X	X
Notoacmea persona				X		X	X	X		X	
Notoacmea fenestrata			X				X				
Cryptobranchia alba						X					
Calliostoma ligature						X					
Margaritas sp.			X			X		X	X		X
Margaritas olivaceus							X				
Margaritas helicinus		X	X	X		X	X	X	X	X	X
Margaritas pupillus			X		X	X	X		X		X
Margaritas succinctus											X
Margaritas beringensis				X							X
Littorina sitkana	X	X	X	X	X	X	X	X	X	X	X
Littorina scutulata	X	X	X	X	X	X	X	X	X	X	X
Littorina saxatilis										X	
Lacuna sp.		X				X	X	X	X	X	X
Lacuna carinata		X	X			X	X	X	X	X	
Lacuna variagata				X							
Lacuna marmorata	X	X	X	X	X	X	X	X	X	X	X
Lacuna vincta		X	X	X	X		X	X	X		X
Alvinia sp.						X			X		X
Alvinia aurivillii				X							
Alvinia compacta				X	X	X	X		X		X
Cingula sp.				X		X			X		X
Barleeia sp.				X					X		X
Barleeia haliotifila									X		
Barleeia subtenuis									X		

SITES

SPECIES	Ocean Cape	Cape Yakataga	Katalla Bay	Cape St. Elias	Port Etches	Zaikof Bay	Macleod Harbor	Squirrel Bay	Latouche Point	Anchor Cove	Gore Point
MOLLUSCA-continued											
Bittium sp.									x		
Bittium.munitum						x	lx				
Cerithiopsis sp.	–		x		x		x	x	x	x	
Cerithiopsis stejnegeri			x	x			x		x	x	
Cerithiopsis stephansae									x		
Crepidula sp.						lx	x				
Crepidula nummaria						x			x	x	
Trichotropis insignis					x	x			x		
Trichotropis cancellata						x					
Natica clausa					x						
Velutina sp.			xl								
Fusitriton oregonensis											
Ocenebra interfossa						x			x		
Urosalpinx lurida									x		
Trophonopsis multicostatus									x		
Nucella sp.	x		x			x	x		x		x
Nucella canaliculata						x	x			x	x
Nucella lamellosa		x	x	x	x	x	x	x	x	x	x
Nucella lima	x	x	x				x		x	x	x
Buccinum sp.	x					x	x				
Buccinum baeri				x			x		x		x
Searlesia dira			x	x	x		x		x	x	x
Amphissa columbiana						x					
Mitrella sp.							x				x
Mitrella rosacea							x		x		
Mitrella tuberosa					x		x		x		
Mitrella gouldi							x		x		x
Nassarius mendicus									x		
Odostomia sp.		x	x	x	x		x	x	x	x	
Odostomia hagemeisteri						x					
Turbonella sp.									x		
Diaphana minuta	[redacted]										
Cylichna alba						x			x		
Dorididae						x			x		
Acanthodoris sp.						x					
Onchidella borealis	x				x		x	x	x	x	x
Siphonaria thersites		x						x	x	x	x
Aglaja diomedeum								x			
Granulina margaritula						x					

Appendix 1 . Continued

SPECIES	Ocean Cape	Cape Yakataga	Katalla Bay	Cape St. Elias	Port Etches	Zaikof Bay	Macleod Harbor	Squirrel Bay	Latouche Point	Anchor Cove	Gore Point
ARACHNIDA											
Acarina			X								X
Halacaridae	X				X	X	X	X	X	X	X
Pseudoscorpionida						X			X	X	X
Pycnogonida			X	X			X			X	
Phoxichilidium quadradentatum			X			X			X		
Phoxichilidium femoratum					X	X				X	X
Ammothea sp.							X		X		
Ammothea alaskensis							X				
Ammothea gracilipes							X	X			
Ammothea latifrons							X				
Ammothea pribilofensis	X	X		X			X		X		X
Achelia chelata							X				X
Achelia borealis											X
Pycnogonidae		X									
CRUSTACEA											
Platycopa		X			X	X	X		X	X	
Harpacticoida	X	X		X		X	X	X			X
Peltidaidae						X				X	
Calanus sp.						X					
Calanus plumchrus	X										
Metridia lucens		X									
Thoracica		X	X								
Balanidae						X					
Balanus sp.		X	X	X		X	X			X	
Balanus balanoides			X			X	X				
Balanus cariosus	X	X	X l		X	X	X	X		X	X
Balanus crenatus	X										
Balanus glandula	X	X	X	X	X	X	X	X	X	X	X
Balanus nubilis						X					
Balanus rostratus			X								
Chthamalus dalli		X	X	X		X"	X		X	X	X
Mysidacea				X							
Mysis sp.				X							
Eudorella emarginata						X					
Diastylis sulcata										X	
Campylaspis sp.			X			X	X				
Campylaspis verrucosa			X			X	X				
Campylaspis affinis			X			X	X				
Cumacea			X	X							X

Appendix 1 . Continued

SPECIES	Ocean Cape	Cape Yakataga	Katalla Bay	Cape St. Elias	Port Etches	Zaikof Bay	Macleod Harbor	Squirrel Bay	Latouche Point	Anchor Cove	Gore Point
CRUSTACEA-continued											
Cumella sp.			X			X	X		X		
Tanaidacea			X				X				
Tanaidae			X	X		X	Xl		X	X	
Isopoda				X		X					
Synidotea sp.				X							
Synidotea ritterii				X							
Pentidotea resects		X									
Pentidotea wosnesenskii	X′	X	X	X	X″	X	X	X	X	X	X
Idotea fewkesi			X	X			X		X	X	X
Sphaeromatidae	X	X	X			X	X	X		X	
Gnorimosphaeroma oregonensis	X	X	X	X	X	X	X		X		
Exosphaeroma sp.			X	X	X				X		X
Exosphaeroma amplicauda		X	X	X					X		X
Dynamenella sp.							X				
Dynamenella sheareri	X		X	X					X	X	X
Ianiropsis k. kincaidi	X		X	X		X	X		X		
Munna sp.	X		X		X	X	X	X	X	X	X
Munna stephenseni			X		X	X	X	X	X	X	X
Munna chromatocephala	X			X		X			X	X	
Amphipoda	X	X	X	X		X	X	X	X	X	X
Odius carinatus						X					
Ampithoe sp.				X		X				Xl	
Ampithoe similans	X	X	X	X	X	X	X	X	X	X	X
Ampithoe lindbergi						X				X	
Atylus sp. ″			X			X					
Calliopiidae		X				lX					
Oligochinus lighti		X	X		X	X	X	X	X	X	X
Calliopiella pratti		X	X	X		X	X	X	X		
Corophiidae			″ A								
Corophium sp.			X	X		X			X		
Eusiridae		X	X			X			X	X	X
Paramoera sp.						X		X		X	
Paramoera columbiana		X	X	X	X	X	X	X	X	X	X
Pontogeneia sp.		X	X	X		X			X		
Gammaridae			X								
Anisogammarus sp.		X	X								
Anisogammarus subcarinatus		X	X								
Melita sp.						X	X	X			
Eohaustorius washingtoniensis	X										
Pontoporeia sp.						X					

Appendix 1 . Continued

SPECIES	Ocean Cape	Cape Yakataga	Katalla Bay	Cape St. Elias	Port Etches	Zaikof Bay	Macleod Harbor	Squirrel Bay	Latouche Point	Anchor Cove	Gore Point
CRUSTACEA-continued											
Najna conciliorum				X					X	X	
Hyalidae	X			X		X	X	X	X	X	X
Allorchestes sp.	X										
Allorchestes maleolus					X		X				
Allorchestes angustus							X				
Hyale sp.		X				X	X		X		
Hyale rubra			X	X	X	X	X	X	X	X	X
Hyale grandicornis								I	Ix..		
Parallorchestes sp.		X	X .				X	X			
Parallorchestes ochotensis	X	X	X	X	X	X	X	X	X	X	X"
Photis sp.							X		X		
Photis brevipes						X			X		
Photis spasskii									X		
Photis bifurcata									X		
Protomedeia sp.									X....		
Protomedeia fasciata										X	
Ischyrocerus sp.	X	X	X	X		X	X		X	X	
Ischyrocerus anguipes				X		X	X		X		
Jassa sp.	X										
Jassa pulcella				X			X		X		
Anonyx sp.		X									
Oedicerotidae										X	
Pleustidae	X			X		X				X	
Parapleustes sp.					X						
Parapleustes nautilus			X	X	X	X	X	X	X	X	
Parapleustes pugettensis						X	X		X		
Pleustes sp.						X			X		
Pleustes panopia						X					
Stenopleustes uncigera						X			X		
Podoceridae									X'		
Stenothoidae						X			X	X	X
Metopella sp.						X					
Metopelloides sp.						X	X	X	X	X--	
Caulloramphus spiniferum									X		
Talitridae		X	X				X	X			
Parathemisto libellula						X					
Caprellidae		X		X	X		X		X	X	
Decapoda							X		X	X	
Heptacarpus brevirostris			X							x	

SPECIES	Ocean Cape	Cape Yakataga	Katalla Bay	Cape St Elias	Port Etches	Zaikof Bay	Macleod Harbor	Squirrel Bay	Latouche Point	Anchor Cove	Gore Point
CRUSTACEA-continued											
Callianassa sp.						x		x			
Paguridae											X
Pagurus sp.			x	x		x				x	
Pagurus beringanus								x	x	x	
Pagurus h. hirsutiusculus		x	x	X	x	X	X	x	x	X	X
Chionoecetes sp.											
Pugettia gracilis			X	X	X	X			X	X	X
Cancer productus											
Cancer oregonensis				X		x	x		x	x	
Telemessus cheiragonus						X	X				
INSECTA											
Insects	X	x	x	x	X	X	x	x	x	x	x
Anurida maritima	x							x	x	x	x
Diptera	x	x	x	x		x	x			x-	x
Chironomidae	X	X	X	X	X	X	x	X	X	X	
Culicidae	'x	x									
Dolichopodidae	x										X
Coleoptera		X	X			X				X	
Staphinidae	x	X		x		x	x				x
SIPUNCULIDA											
Sipunculida				x	x	X			X	x	
ECHUROIDEA											
Bonelliopsis alaskana				x							
Echiurus e. alaskanus			X		X	X	X				
BRYOZOA											
Bryozoa		x	X	X	X	X	x	x	x	x	X
Membranipora membranacea						x					
Terminoflustra sp.								X			
Terminoflustra membraceotruncata			X								
Cauloramphus spiniferum			X		X		X				
Callopora sp.			X		X						
Callopora lineata								x			
Tegella robertsoniae					X						
Microporina sp.		X		X			X			X	

Appendix 1 . Continued

SPECIES	Ocean Cape	Cape Yakataga	Katalla Bay	Cape St. Elias	Port Etches	Zaikof Bay	Macleod Harbor	Squirrel Bay	Latouche Point	Anchor Cove	Gore Point
BRYOZOA-continued											
Microporina borealis					x	x	x	x	x		
Tricellaria occidentalis									x		
Dendrobeania lichenoides					x			X			
Hippothoa cornuta									X		
Hippothoa hyalina		X			X	X	X	X	X	X	
Hipplodiplosia sp.							X	X			
Microporella sp.			X						X		
Microporella cribrosa			X								
Microporella vibraculifera							X				
Cryptosula pallasiana					X	X		X		X	
Lagenipora socialis					X		X	X			
Costazia sp.			X								
Costazia surcularis			X								
Costazia ventricosa			X								
Costazia robertsoniae							X				
Myriozoum coarctatum							X				
Myriozoum subgracile							X				
Myriozoella plana					X		X	X			
Diaperoecia sp.					X						
Filicrisia sp.										X	
Crisea sp.									X		
Crisea occidentalis					X		X	X		X	
Heteropora sp.							X				
Borgiola pustulosa						X					
Disporella sp.				X	X	X					
Alcyonidium sp.										X	
Alcyonidium polyoum										X	
Flustrellidae									X		
Flustrella sp.								X			
Flustrella corniculata								X			
Bowerbankia imbricata										X	
BRACHIOPODA											
Terebratalia transversal						X					
ECHINODERMATA											
Asteroidea		X				X		X	XX	X	X
Henricia sp.						X	X				
Henricia leviuscula									X	X	

Appendix 1 . Continued

SPECIES	Ocean Cape	Cape Yakataga	Katalla Bay	Cape St. Elias	Port Etches	Zaikof Bay	Macleod Harbor	Squirrel Bay	Latouche Point	Anchor Cove	Gore Point
ECHINODERMATA-continued											
Evasterias troschelii					x						x
Leptasterias sp.			x			x					x
Leptasterias groenlandica											x
Leptasterias hexactis	x	x	x	x	x	x		x		x	x
Pisaster ochraceus						x				x	
Pycnopodia helianthoides						x					
Strongylocentrotus droebachiensis			x	x	x	x	x		x	x	
Strongylocentrotus purpuratus										x	
Ophiuroidea		x				x					
Cucumaria sp.										Y	
Cucumaria pseudocurata					x	x			x	x	x
UROCHORDATA											
Urochordata				x	x	x		x	x		
TELEOSTEI											
Teleostei											x
Clinocottus acuticeps											
Oligocottus maculosus											x
Liparis callyodon											x
Anoplarchus purpurescens											
Phytichthys chirus									x	x	x
Xiphister mucosa						x					
Phells I aeta											
Total Species	109	178	200	183	155	339	267	136	301	284	169

Appendix 2. Presence (x) or absence (blank) of species of plants and invertebrates on sandy beaches at six sites in the eastern Gulf of Alaska.

SPECIES	Ocean Cape	Cape Yakataga	Kanak Island	Softuk Spit	Big Egg Island	Hook Point
CHLOROPHYTA						
Chlorophyta			x			x
Monostroma sp.			x			
CRYSOPHYTA						
Crysophyta			x			
Bacillariophyceae			x			
Centrales						
Pennales						
PHAEOPHYTA						
Ectocarpus sp.						x
RHODOPHYTA						
Rhodophyta			x			
Corallinaceae			x			x
Iridaea sp.			x			
Palmaria palmata			x			
Neoptilota sp.					x	
Odonthalia sp.			x			
PROTOZOA						
Foraminifera						x
Cnidaria						
Cnidaria		x				
RHYNCHOCOELA						
Rhynchocoela		x	x			x
Emplectonema gracile				x		
ANNELIDA						
Polychaeta			x			x
Anaitides maculata			x			
Eteone longa		x	x	x		x
Syllidae			x			
Nephtys sp.			x			
Nephtys caeca			x			
Glycinde armigera			x			
Scoloplos armiger			x			

Appendix 2 Continued

SPECIES	Ocean Cape	Cape Yakataga	Kanak Island	Softuk Spit	Big Egg Island	Hook Point
ANNELIDA-continued						
Paraonis sp.			X			
Spionidae			X			
Pygospio sp.		X				
Nerine cirratulus			X			
Magelona pitelkai			X			
Cirratulus cirratus			X			
Thoracophelia sp.					X	
MOLLUSCA						
Pelecypoda			X			
Mytilus edulis		X				
Macoma balthica			X			
Lacuna vincta		X				
CRUSTACEA						
Harpacticoidea						
Calanus plumchrus	X				X	
Metridia lucens		X				
Mysidacea						X
Archeomysis grebnitzkii	X		X	X		
Cumacea			X			
Lamprops sp.			X			
Lamprops quadriplicata			X			
Amphipoda	X	X	X	X		X
Eohaustorius washingtoniensis			X	X	X	
Hyale rubra			X			
Paraphoxus sp.			X			
Majiidae	X					
Chionoecetes sp	X					
INSECTA						
Culicidae	X					
BRYOZOA						
Bryozoa		X				
OPHIUROIDEA						
Ophiuroidea		X				
Total Species	6	10	35	6	4	9

Appendix 3. Presence (x) or absence (blank) of species of **plants and invertebrates on muddy beaches at** two sites in the eastern Gulf of Alaska.

SPECIES	Boswell Bay	Middleton Island
CHLOROPHYTA		
Chlorophyta	x	x
Enteromorpha sp.		
Enteromorpha clathrata	x	
Enteromorpha crinita	x	
Enteromorpha intestinalis	x	
Ulva sp.		x
Ulva lactuca		x
Cladophora sp.	x	
CRYSOPHYTA		
Crysophyta	x	
Bacillariophyceae	x	
PHAEOPHYTA		
Phaeophyta		
Diet.YosltIhonales	x	
Scytosiphon lomentaria	x	
Fucus distichus	x	x
RHODOPHYTA		
Rhodophyta	x	
Cryptosiphonia woodii	x	
Bossiella plumosa		x
Gigartina papillata		x
Palmaria palmata		x
Rhodymenia pertusa		x
Pterosiphonia bipinnata	x	
Odonthalia floccosa	x	x
PHYCOMYCETES		
Phycomycetes	x	
ANTHOPHYTA		
Potamogetonaceae	x	
PROTOZOA		
Protozoa	x	
Foraminifera	x	

SPECIES	Boswell Bay	Middleton Island
CNIDARIA		
Eudendrium sp.	X	
TURBELLARIA		
Turbellaria	X	
RHYNCHOCOELA		
Rhynchocoela	X	X
Emplectonema gracile	X	
NEMATODA		
Nematoda	X	X
ANNELIDA	X	X
Polychaeta	X	X
Polynoidae	X	
Gattyana cirrosa	X	
Gattyana treadwelli	X	
Harmothoe imbricata	X	
Polyodontidae		X
Pholoe minuta	X	
Phyllodocidae	X	
Anaitides maculata	X	
Eteone sp.	X	
Eteone pacifica	X	X
Eteone longa	X	X
Eulalia viridis	X	
Mysta barbata	X	
Syllis sp.	X	
Typosyllis alternata	X	
Typosyllis elongata	X	
Typosyllis pulchra	X	
Typosyllis fasciata		X
Typosyllis hyalina	X	
Exogone molesta	X	
Exogone verrugera	X	
Syllides japonica		X
Nereis sp.	X	X
Nereis procera		X
Nereis vexillosa		X

Appendix 3 . **Continued**

SPECIES	Boswell Bay	Middleton Island										
ANNELIDA-continued												
Nephtys sp.	X											
Nephtys ciliata	X											
Nephtys caeca	X											
Nephtys cornuta	X											
Nephtys schmitti	X											
Glycera capitata		X										
Glycinde picta	X											
Haploscoloplos sp.	X											
Haploscoloplos elongatus	X											
Haploscoloplos panamensis	X											
Scoloplos armiger												
Aricidea sp.	X											
Aricidea suecica	X											
Tauberia gracilis	X											
Polydora sp.	X											
Polydora caeca	X											
Polydora caulleryi												
Polydora ciliata	X											
Polydora quadrilobata	X											
Spio filicornis	X	X										
Spiophanes bombyx	X	X										
Spiophanes cirrata	X	X										
Rhynchospio sp.	X	X										
Pygospio sp.		X										
Pygospio californica		X										
Pygospio elegans		X										
Cirratulidae	X											
Caulleriella sp.	X											
Tharyx sp.	X											
Tharyx multifilis	X											
Tharyx parvus	X											
Chaetozone setosa	X											
Dodecaceria sp.	X											
Capitellidae	X	X										
Capitella capitata		X										
Heteromastus filiformis	X	X										
Abarenicola sp.	X											
Abarenicola pacifica	X	X										
Maldanidae	X											

Appendix 3 . Continued

SPECIES	Boswell Bay	Middleton Island
ANNELIDA-continued		
Owenia fusiformis	X	
Owenia pacifica	X	
Myriochele heeri		X
Cistenides brevicoma	X	
Pectinaria belgica	X	
Ampharete arctica	X	
Asabellides sibirica	X	
Glyphanostomur pallescens	X	
Sabellidae	X	
Chone infundibuliformis	X	
Chone cincta	X	
Fabricia sabella	X	
Fabricia minuta [1]	X	
Laonome sp.	X	
Pseudosabellides littorals	X	
Oligochaeta	X	X
Enchytraeidae	X	X
MOLLUSCA		
Pelecypoda	X	
Mytilus edulis	X	X
Pseudopythina compressa	X	
Clinocardium sp.	X	
Clinocardium ciliatum	X	
Clinocardium nuttallii	X	
Saxidomus gigantea	X	
Protothaca staminea	X	
Macoma sp.	X	
Macoma obliqua	X	
Macoma balthica	X	X
Mya sp.	X	
Mya arenaria	X	
Mya elegans	X	
Hiatella arctica	X	
Gastropoda	X	
Collisella pelts	X	
Collisella ochracea	X	
Margaritas helicinus	X	
Littorina sitkana	X	X

[1] Banse = Oriopsis minuta (Berkeley and Berkeley)

SITES

SPECIES	Boswell Bay	Middleton Island
MOLLUSCA-continued		
Littorina aleutica	x	
Littorina scutulata	X	
Lacuna carinata	x	
Lacuna marmorata	x	
Cerithiopsis sp.	-x	
Cerithiopsis stejnegeri	x	
Nucella sp.	X 1"	
Nucella lamellosa		
Nucella lima	x	
Odostomia sp.	X	
Cylichna sp.	X	
Aglaja diomedeum	x	
ARACHNIDA		
Halacaridae	x	
Pseudoscorpionida		
CRUSTACEA		
Crustacea	X	
Platycopa	x	x
Harpacticoidea	x	X
Calanus plumchrus	X	
Balanidae	X	
Balanus sp.	-X	
Balanus balanoides	x	
Balanus crenatus	-x	
Balanus glandula	x	
hthamalus dalli	x	
Cumacea	x	
Campylaspis sp.	X	
Campylaspis verrucosa	X	
Campylaspis affinis	X	
Tanaidacea	X	
Pentidotea wosensenskii		X
Gnorimosphaeroma oregonensis	x	
Amphipoda	X	
Ampithoe simulans		x
Calliopiidae	X	
Oligochinus lighti	x	x

Appendix 3 . Continued

SPECIES	Boswell Bay	Middleton Island
CRUSTACEA-continued		
Corophiidae	x	
Corophium sp.	x	
Paramoera columbiana	x	
Anisogammarus sp.	x	x
Anisogammarus locustoides	x	
Parallorchestes sp.	x	
Parallorchestes ochotensis	x	
Parapleustes nautilus	x	
Talitrus sp.	x	
Callianassa sp.	x	
Pagurus sp.	x	
Pagurus h. hirsutiusculus	x	
Chionoecetes sp		x
INSECTA		
Insects	x	x
Diptera	x	
Chironomidae	x	x
ECHIUROIDEA		
Echiuroidea	x	
Echiurus E. alaskanus	x	
BRYOZOA		
Bryozoa	x	x
BRACHIOPODA		
Brachiopoda		x
Total Species	168	50